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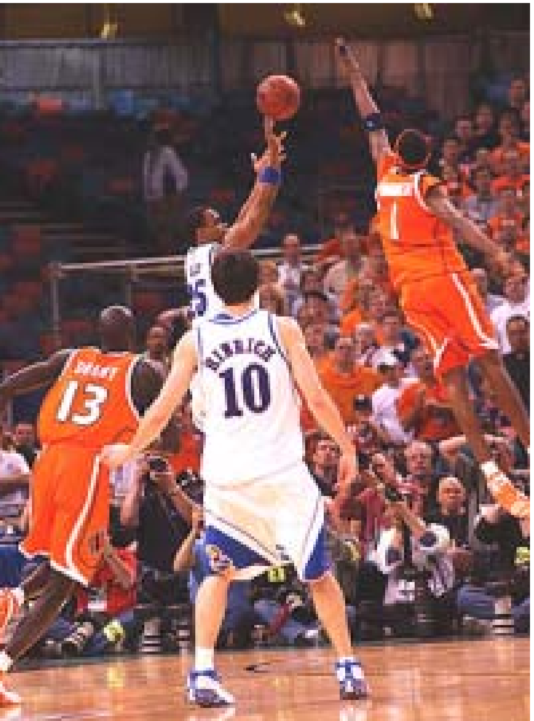
Heavy Quark Physics



Far too much interesting Material to include in 40 min. Apologies in advance.

Physics Goals

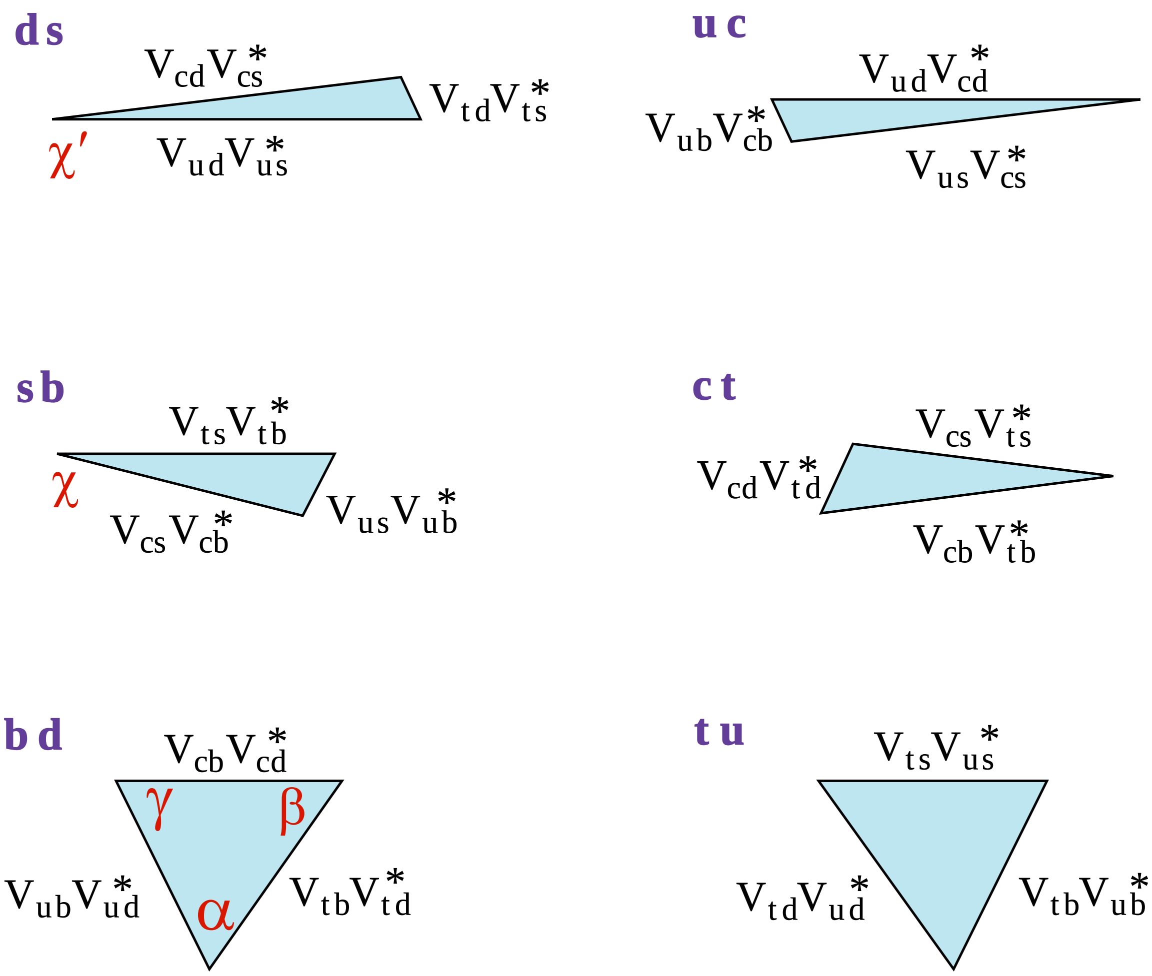
- Discover, or help interpret, New Physics found elsewhere using b & c decays - There is New Physics out there: Standard Model is violated by the Baryon Asymmetry of Universe & by Dark Matter
- Measure Standard Model parameters, the "fundamental constants" revealed to us by studying Weak interactions
- Understand QCD; necessary to interpret CKM measurements

The Basics: Quark Mixing & the CKM Matrix

$$V = \begin{array}{c} \\ u \\ c \\ t \end{array}\!\!\begin{array}{c} \begin{array}{ccc} d & s & b \end{array} \\ \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3\left(\rho-i\eta\left(1-\frac{1}{2}\lambda^2\right)\right) \\ -\lambda & 1-\frac{1}{2}\lambda^2-i\eta A^2\lambda^4 & A\lambda^2\left(1+i\eta\lambda^2\right) \\ A\lambda^3\left(1-\rho-i\eta\right) & -A\lambda^2 & 1 \end{pmatrix} \end{array} \quad \begin{array}{l} \xrightarrow{\quad} \text{mass} \\ \downarrow \\ \text{m} \\ \text{a} \\ \text{s} \\ \text{s} \end{array}$$

- A, λ, ρ and η are in the Standard Model fundamental constants of nature like G, or α_{EM}
- η multiplies i and is responsible for CP violation
- We know λ=0.22 (V_{us}), A~0.8; constraints on ρ & η

The 6 CKM Triangles



- From Unitarity
- "ds" - indicates rows or columns used
- There are 4 independent phases: β, γ, χ, χ' (α can be substituted for γ or β)

All of The CKM Phases

- The CKM matrix can be expressed in terms of 4 phases, rather than, for example λ, A, ρ, η:

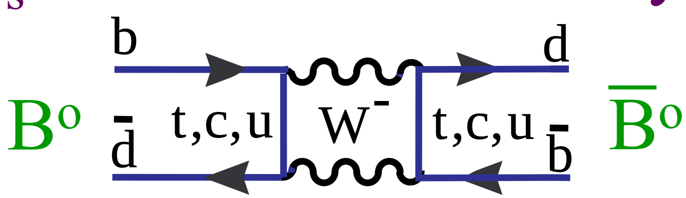
$$\beta = \arg\left(-\frac{V_{tb} V_{td}^{*}}{V_{cb} V_{cd}^{*}} \right) \qquad \gamma = \arg\left(-\frac{V_{ub}^{*} V_{ud}}{V_{cb}^{*} V_{cd}} \right)$$

$$\chi = \arg\left(-\frac{V_{cs}^{*} V_{cb}}{V_{ts}^{*} V_{tb}} \right) \qquad \chi' = \arg\left(-\frac{V_{ud}^{*} V_{us}}{V_{cd}^{*} V_{cs}} \right)$$

- $\alpha = \pi - (\beta + \gamma)$, not independent
- α, β & γ probably large, χ small ~1^{o}, χ' smaller

Required Measurements

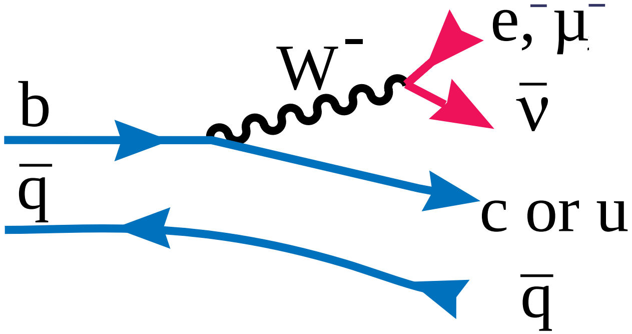
- $|V_{ub}/V_{cb}|^2 = (\rho^2 + \eta^2)/\lambda^2$ use semileptonic B decays
- Δm_d and Δm_s are measured directly in B_d and B_s mixing.



There is a limit on the ratio which is a function of V_{td}/V_{ts} and depends on $(1-\rho)^2+\eta^2$

- ε_K is a measure of CP violation in K_L decays, a function of η, ρ and A
- Asymmetries in decay rates into CP eigenstates f (or other states) measure the angles α, β, γ & χ, sometimes with little or no theoretical model errors

$|V_{ub}|$ a case study



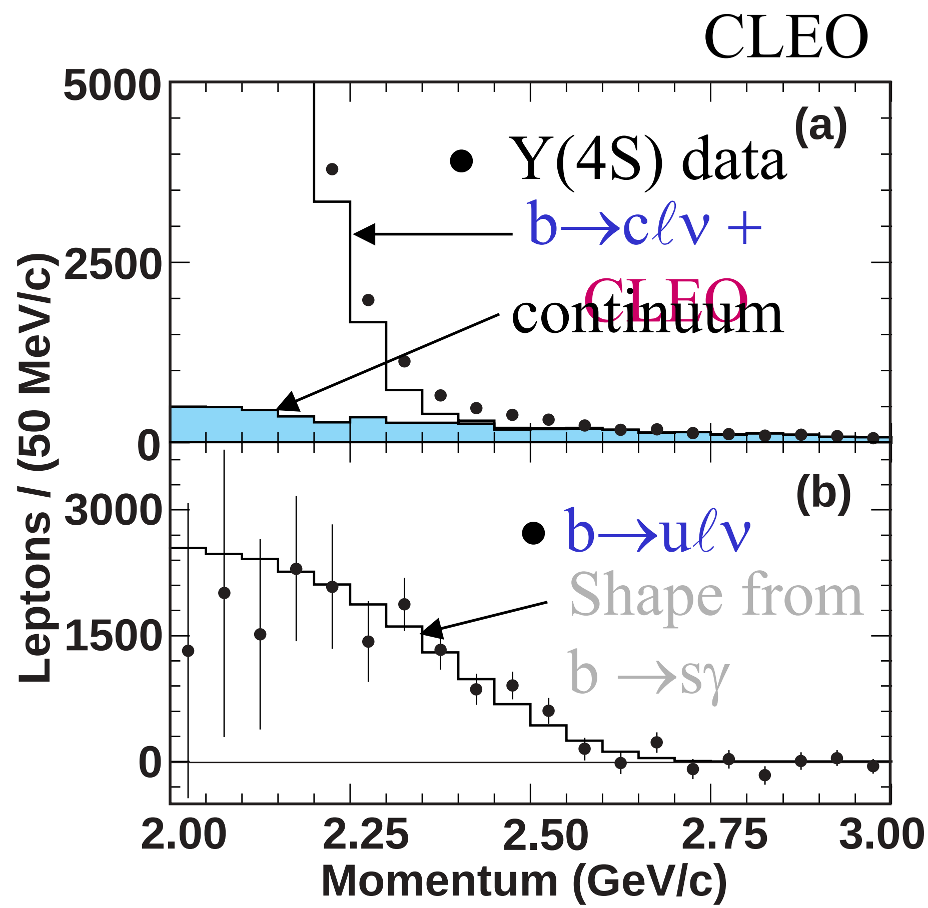
- Use semileptonic decays
  - c >> u, so difficult exp
  - Also difficult theoretically
- Three approaches
  - Endpoint leptons: Clear signal seen first this way; new theory enables predictions
  - Make mass cuts on the hadronic system; plot the lepton spectrum. Problems are the systematic errors on the experiment and the theory.
  - Exclusive $B \rightarrow \pi \ell \nu$ or $\rho \ell \nu$ decays. Data are still poor as is theory. Eventually Lattice Gauge calculations should be able to remove this problem

V_{ub} from lepton endpoint

- V_{ub} both overall rate & fraction of leptons in signal region depends on model. Use CLEO $b \to s\gamma$ spectrum to predict shape
- CLEO: $V_{ub}=(4.08\pm0.34 \pm0.44\pm0.16 \pm0.24)\times10^{-3}$
- BABAR: $V_{ub}=(4.43\pm0.29 \pm0.25\pm0.50 \pm0.35)\times10^{-3}$

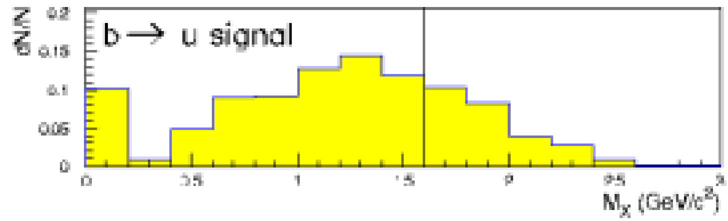
theory errs : V_{ub} formula, using $s\gamma$

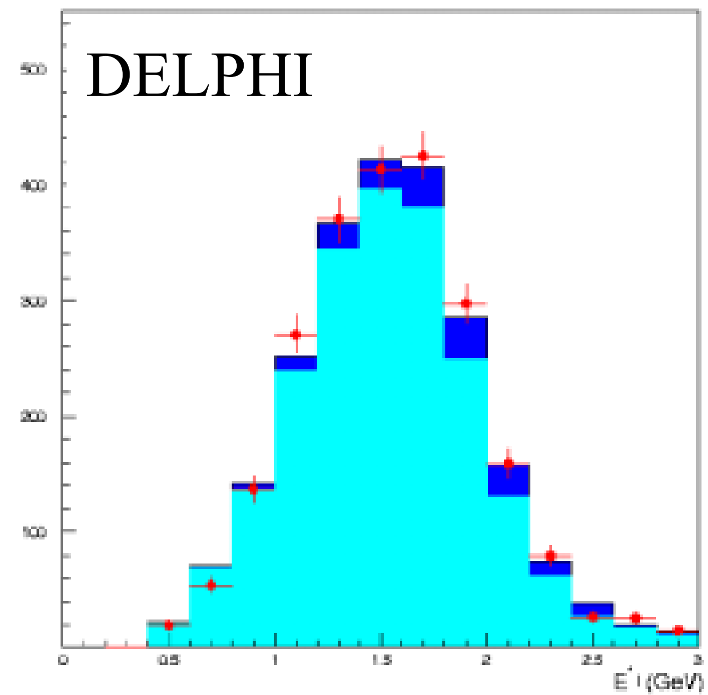
- Luke: additional error $>0.6\times10^{-3}$ due to: subleading twist, annihilation



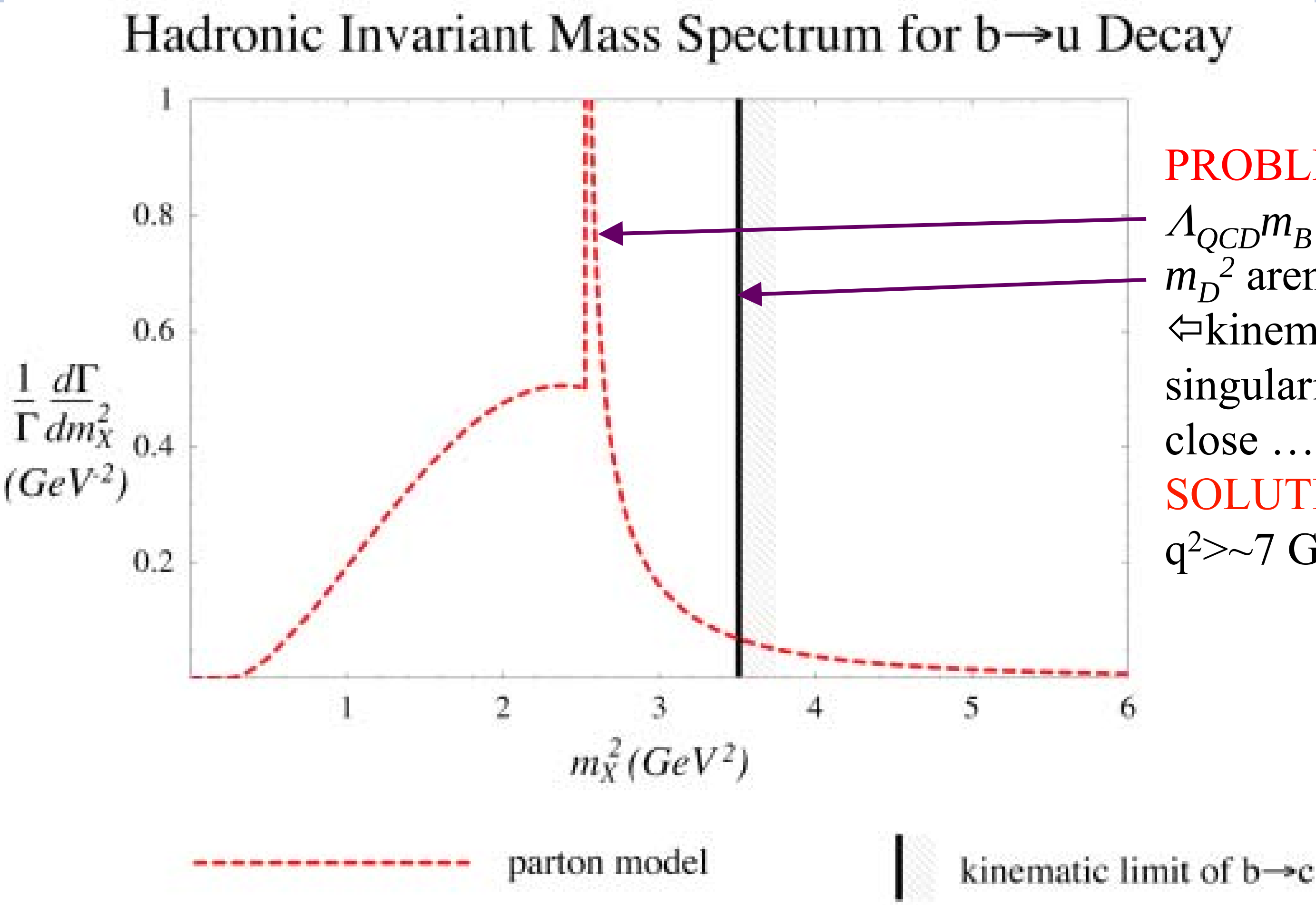
V_{ub} Using Inclusive Leptons

- ALEPH & DELPHI, OPAL select samples of charm-poor semileptonic decays with a large number of selection criteria
- Mass < $M_D \Rightarrow b \rightarrow u$
- Can they understand $b \rightarrow c\ell\nu$ feedthrough < 1% ?
- $|V_{ub}|=(4.09\pm0.37\pm0.44 \pm0.34)\times10^{-3}$





Problem According to Luke

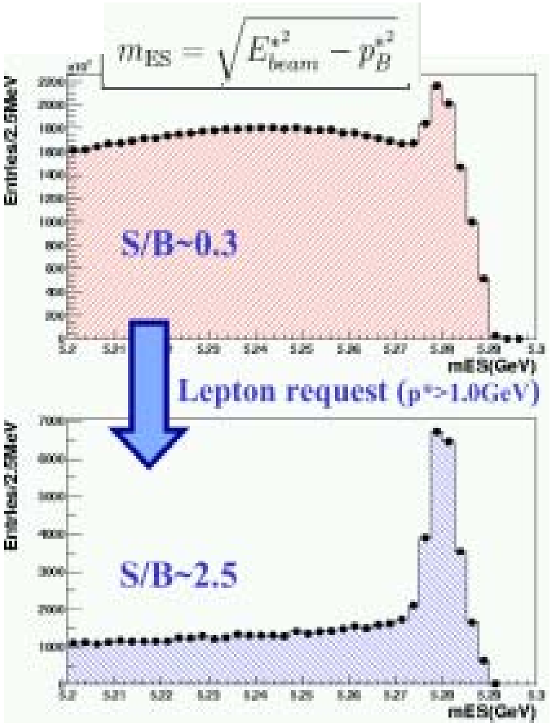


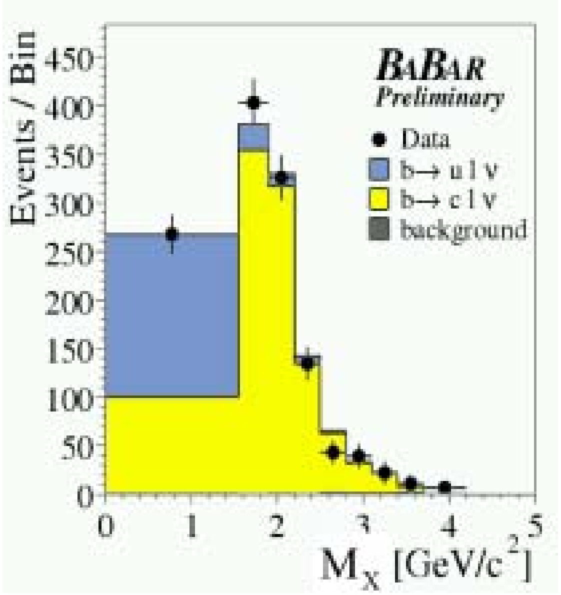
PROBLEM: $\Lambda_{QCD}m_B$ and m_D^2 aren't so different! ⇦kinematic cut and singularity are perilously close …

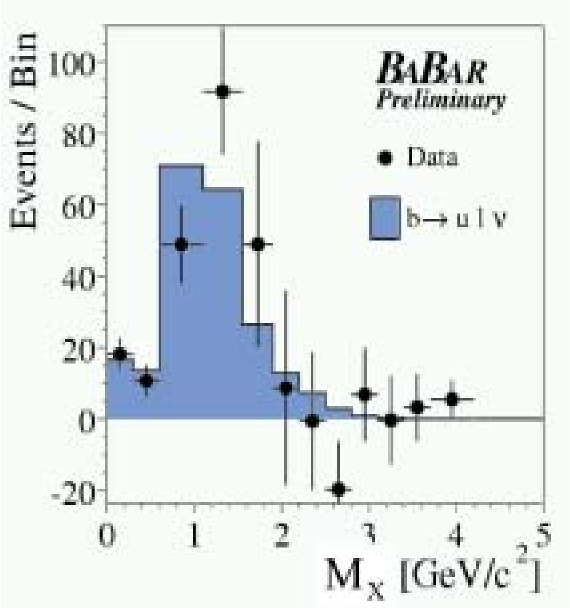
SOLUTION: Also require $q^2 > \sim 7$ GeV^2

V_{ub} using reconstructed tags - BABAR

- Use fully reconstructed B tags







- $|V_{ub}|=(4.52\pm0.31(\mathrm{stat})\pm0.27(\mathrm{sys})$
$\pm0.40(\mathrm{thy})\pm0.09(\mathrm{pert})$
$\pm0.27(1/m_b^3))\ \mathrm{x}10^{-3}$

Preliminary

V_{ub} from Belle

- Two techniques (*Both Preliminary*)

"$D^{(*)}\ell\nu$ tag"

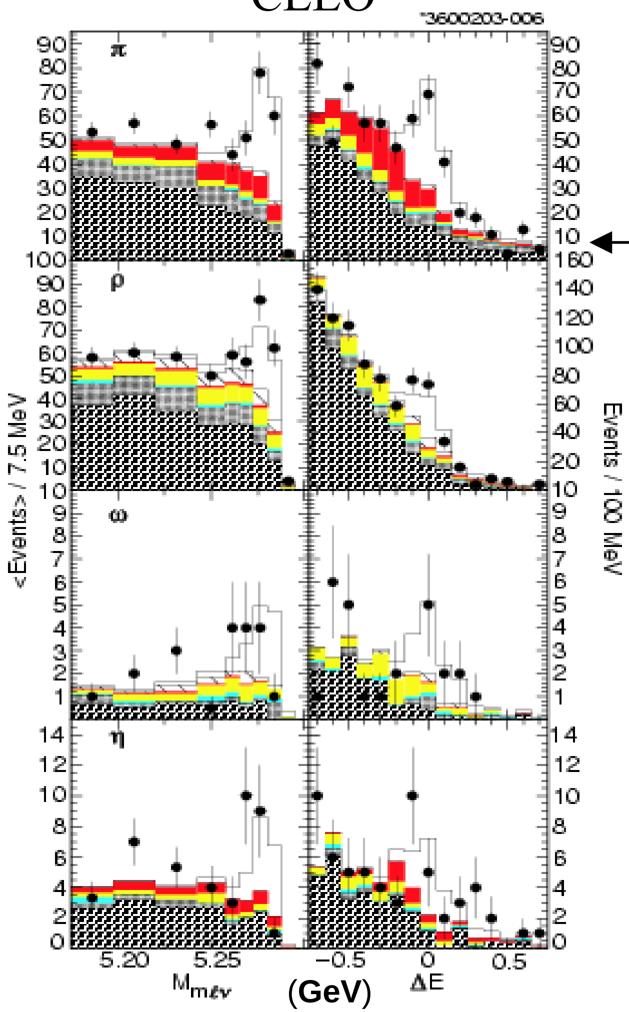
$$|V_{ub}| = 5.00 \underset{\text{stat.}}{\pm 0.60} \underset{\text{syst.}}{\pm 0.23} \underset{b\to c}{\pm 0.05} \underset{b\to u}{\pm 0.39} \underset{\text{theor.}}{\pm 0.36} \times 10^{-3}$$

"ν reconstruction and Annealing uses Mx < 1.5, q2 > 7"

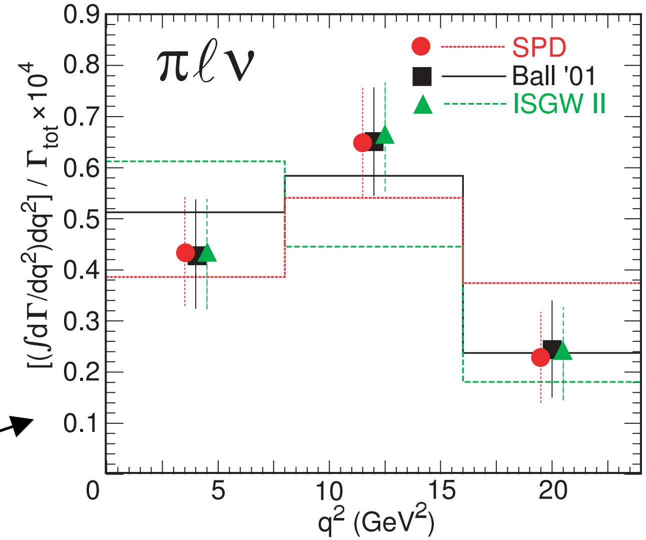
$$|V_{ub}| = 3.96 \underset{\text{stat.}}{\pm 0.17} \underset{\text{syst.}}{\pm 0.44} \underset{b\to c}{\pm 0.34} \underset{b\to u}{\pm 0.26} \underset{\text{theor.}}{\pm 0.29} \times 10^{-3}$$

V_{ub} from exclusives: $B\to\pi\ell\nu$ & $B\to\rho\ell\nu$

CLEO



- Use detector hermeticity to reconstruct ν
- CLEO finds rough q^2 distribution



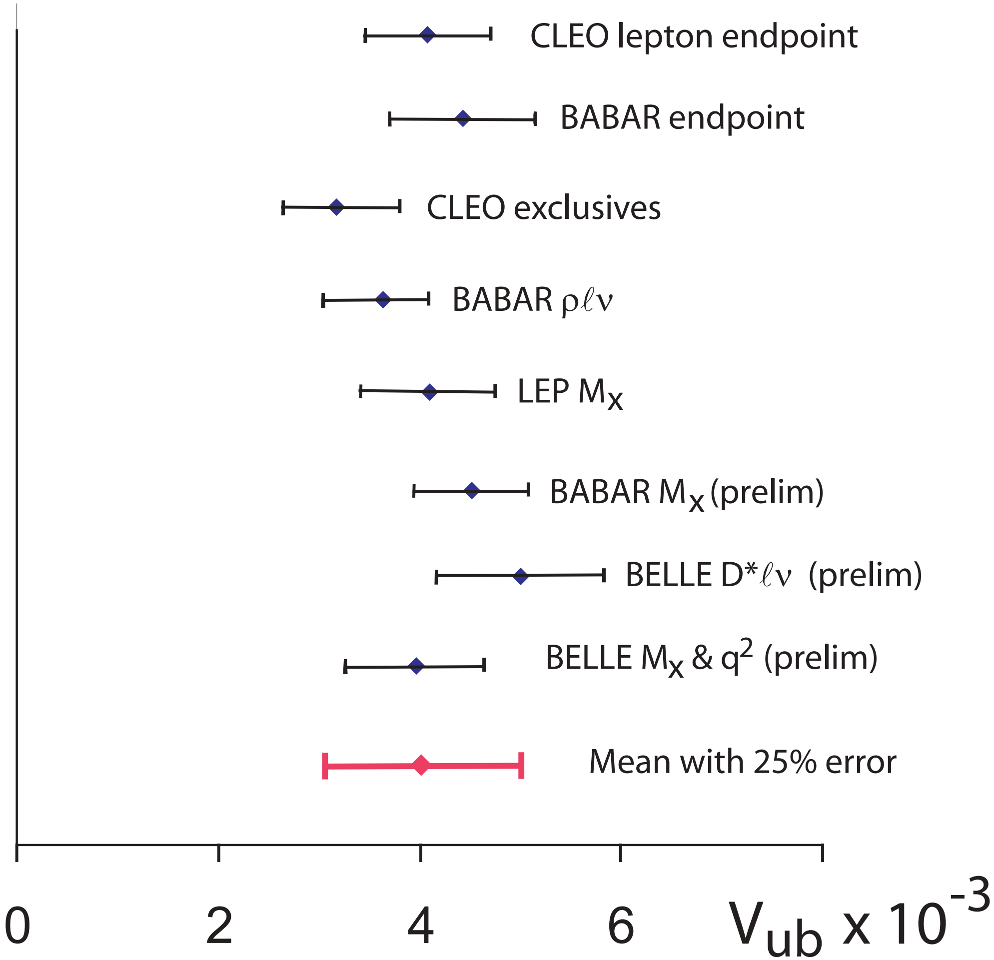
$$|V_{ub}| = \left[3.17\pm0.17\Big|_{stat}\ {}^{+0.16}_{-0.17}\Big|^{exp}_{sys}\ {}^{+0.53}_{-0.39}\Big|^{thy}\ \pm0.03\Big|^{theor}_{\rho\ell\nu\ FF}\right]\times10^{-3}$$

- BABAR finds

$$|V_{ub}| = \left[3.64\pm0.22\Big|_{stat}\ \pm0.03\Big|_{syst}\ {}^{+0.39}_{-0.56}\Big|^{thy}\right]\times10^{-3}$$

$|V_{ub}|$ Summary

- All measurements nicely clustered. RMS ~0.3×10^{-3}
- However, there are theoretical errors that might all have not been included (see Luke)
- Also previous values may have influenced new values
- Safe to say $|V_{ub}|=(4.0\pm1.0)\times10^{-3}$
- Future:
  - More and better tagged data from B-factories
  - Lattice calculations (unquenched) for exclusives in high q^2 region



B_d Mixing in the Standard Model

- Relation between B mixing & CKM elements:

$$x \equiv \frac{\Delta m}{\Gamma} = \frac{G_F^2}{6\pi^2} B_B f_B^2 m_B \tau_B \left|V_{tb}^* V_{td}\right|^2 m_t^2 F\left(\frac{m_t^2}{m_W^2}\right) \eta_{QCD}$$

- F is a known function, $\eta_{QCD} \sim 0.8$
- B_B and f_B are currently determined only theoretically
  - in principle, f_B can be measured, but its very difficult, need to measure $B^o \to \ell\nu$
  - Current best hope is Lattice QCD

B_s Mixing in the Standard Model

$$x_s \equiv \frac{\Delta m_s}{\Gamma_s} = \frac{G_F^2}{6\pi^2} B_{B_S} f_{B_S}^2 m_{B_S} \tau_{B_S} \left| V_{tb}^* V_{ts} \right|^2 m_t^2 F\left(\frac{m_t^2}{m_W^2}\right) \eta_{QCD}$$

- When B_s mixing is measured then we will learn the ratio of V_{td}/V_{ts} which gives the same essential information as B_d mixing alone:
  - $|V_{td}|^2 = A^2\lambda^4[(1-\rho)^2+\eta^2]$ α $1/f_B B_B{}^2$
  - $|V_{td}|^2/\ |V_{ts}|^2 = [(1-\rho)^2+\eta^2]$ α $f_{Bs}B_{Bs}{}^2/f_B B_B{}^2$
  - Circle in (ρ,η) plane centered at (1,0)
- Lattice best value for

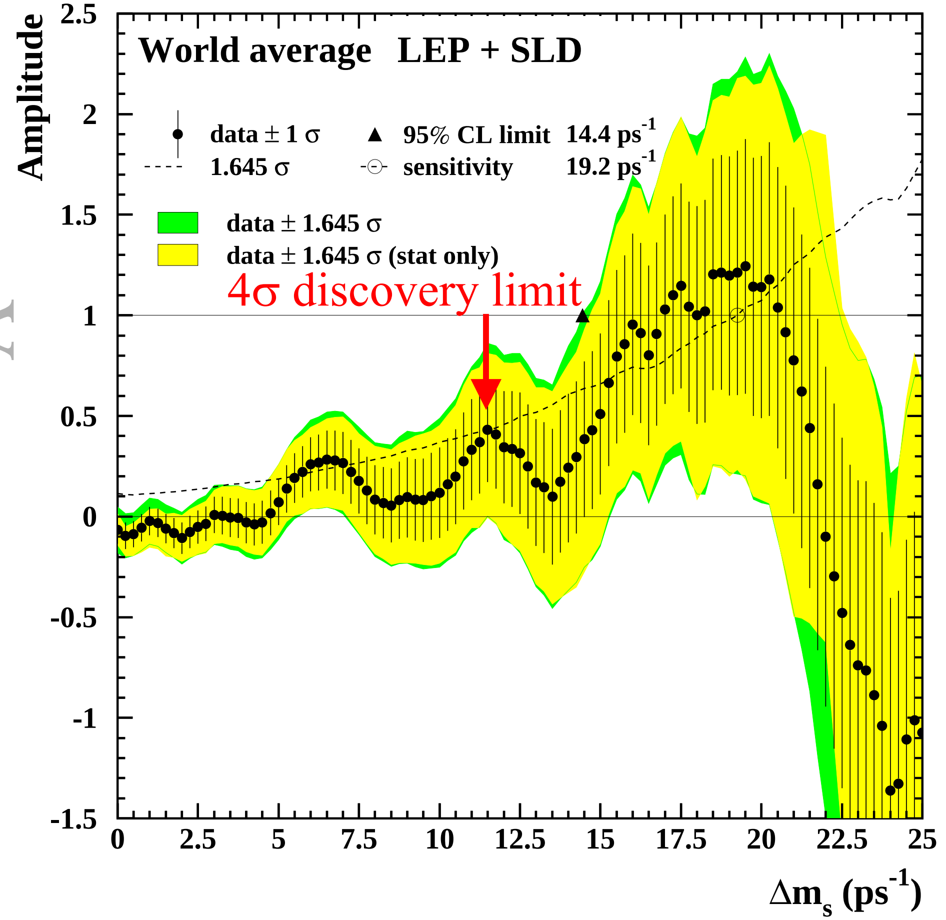
$$\xi = \frac{f_{B_S}\sqrt{B_{B_S}}}{f_{B_d}\sqrt{B_{B_d}}} = 1.24 \pm 0.04 \pm 0.06$$

Partially unquenched

Upper limits on Δm_s

- $P(B_S \rightarrow \overline{B}_S) = 0.5 \times \Gamma_S e^{-\Gamma_S t}[1+\cos(\Delta m_S t)]$
- To add exp. it is useful to analyze the data as a function of a test frequency ω
- $g(t) = 0.5\, \Gamma_S\, e^{-\Gamma_S t}[1+A\cos(\omega t)]$

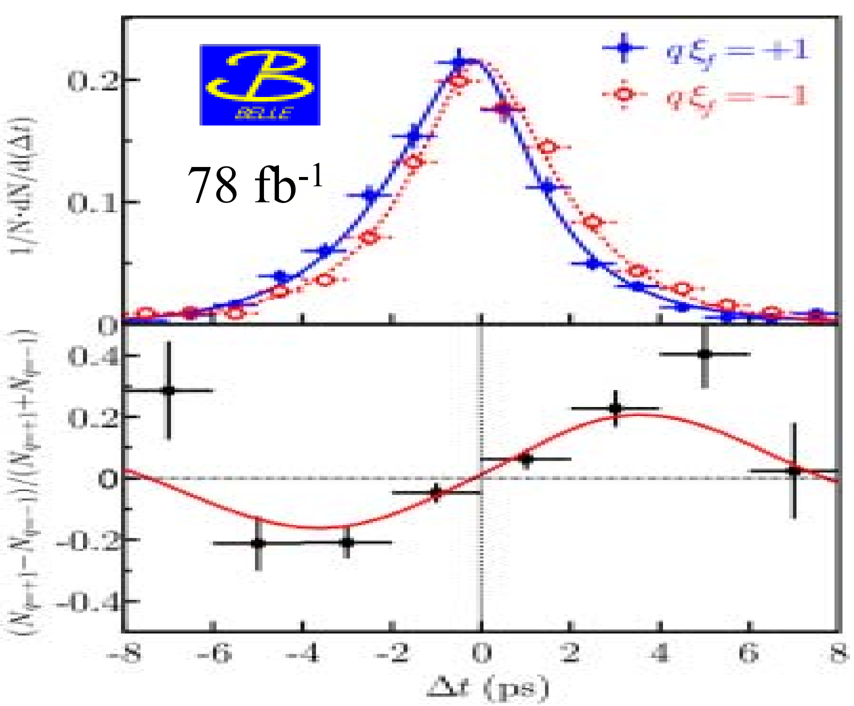
A



Status of sin(2β)

$\sin 2\beta$ = 0.741±0.067±0.034 BABAR
$\sin 2\beta$ = 0.719±0.074±0.035 Belle
$\sin 2\beta$ = 0.73 ± 0.06 Average

No theoretical uncertainties at this level of error



$\overline{B}^0 \rightarrow f_{CP}$

$B^0 \rightarrow f_{CP}$

f_{CP}=J/ψK_s, ψ′K_s, etc..

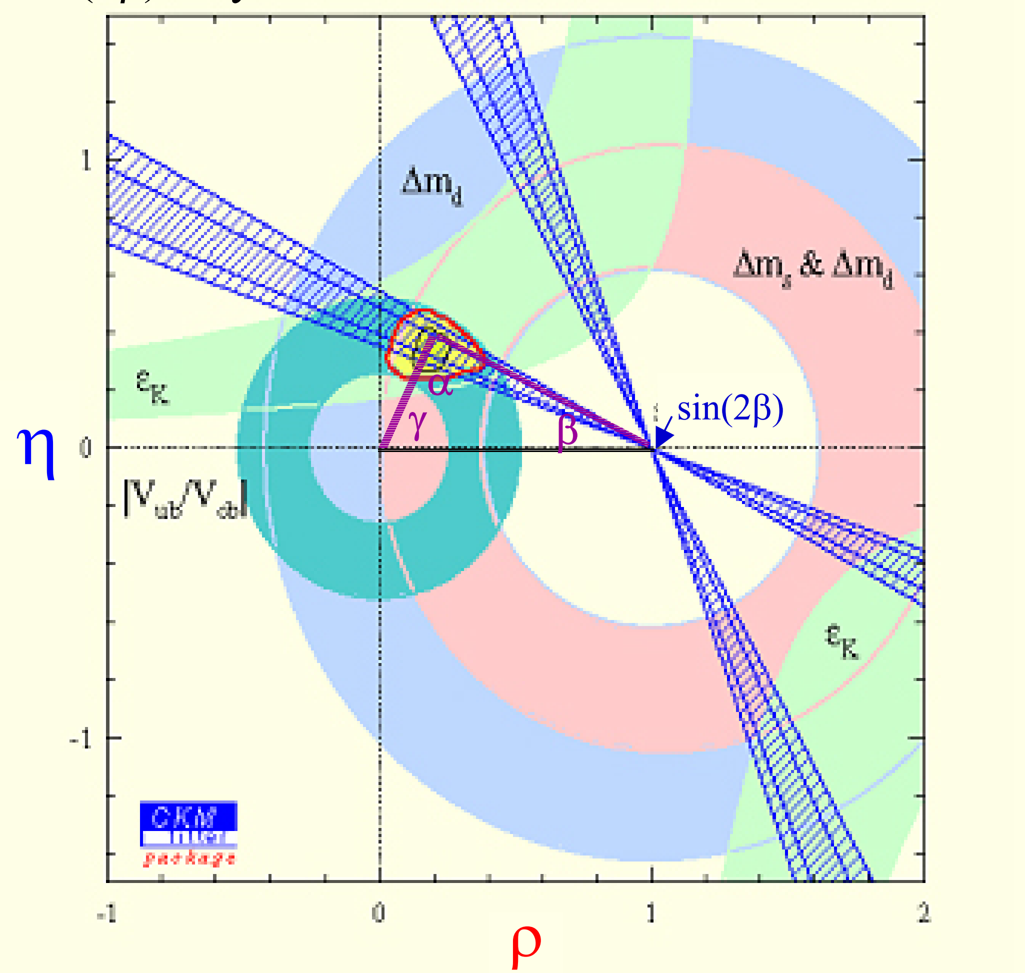
$$A_{CP}(\Delta t) = \frac{N_{\overline{B}} - N_B}{N_{\overline{B}} + N_B}$$

$$= \sin(2\beta)\sin(\Delta m_d \Delta t)$$

Current Status

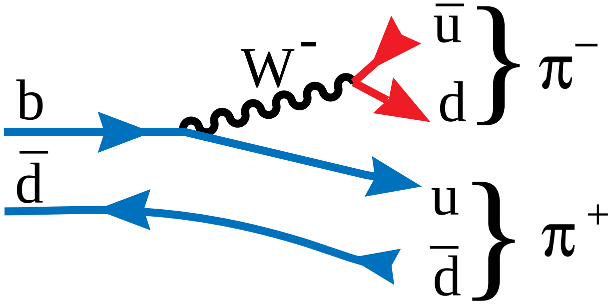
- Constraints on ρ & η from Nir using Hocker et al.
- Theory parameters exist except in Asymmetry measurements, because we measure hadrons but are trying to extract quark couplings. They are allowed to have equal probability within a restricted but arbitrary range
- Therefore large model dependence for V_{ub}/V_{cb}, ε_K and Δm_d, smaller but significant for Δm_s and virtually none for sin(2β). The level of theoretical uncertainties is arguable

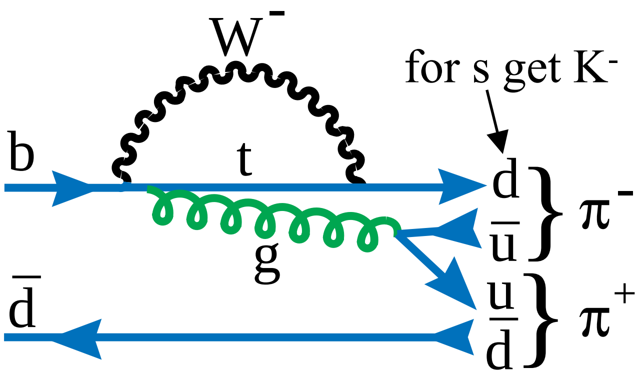
sin(2β) may be consistent with other measurements



$B^o \rightarrow \pi^+\pi^-$

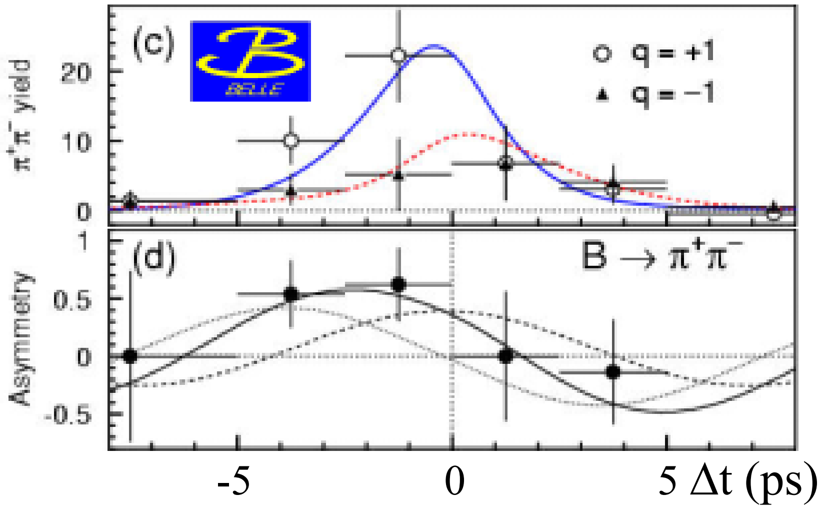
- In principle, the CP asymmetry in $B^o \rightarrow \pi^+\pi^-$ measures the phase α. However there is a large Penguin term (a "pollution") (CLEO+ BABAR+BELLE):
  $\mathcal{B}(B^o \rightarrow \pi^+\pi^-) = (4.8 \pm 0.5)\text{x}10^{-6}$
  $\mathcal{B}(B^o \rightarrow K^\pm\pi^\mp) = (18.6 \pm 1.0)\text{x}10^{-6}$



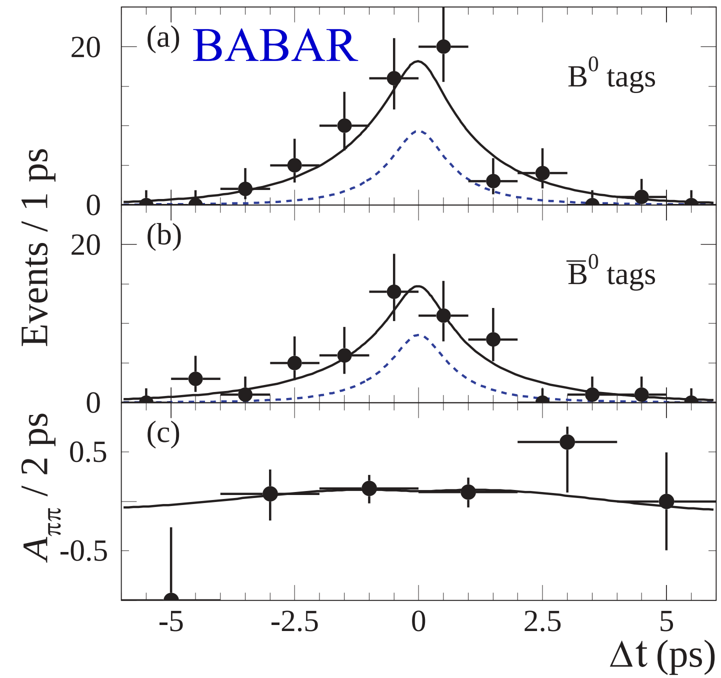


- $A_{CP}(\Delta t) = S_{\pi\pi}\sin(\Delta m_d \Delta t) - C_{\pi\pi}\cos(\Delta m_d \Delta t)$, where $S_{\pi\pi}^2 + C_{\pi\pi}^2 < 1$
- To measure α, use $B^o \rightarrow \rho\pi$ (see Snyder & Quinn PRD 48, 2139 (1993))

Results



Each exp
~80 fb^{-1}



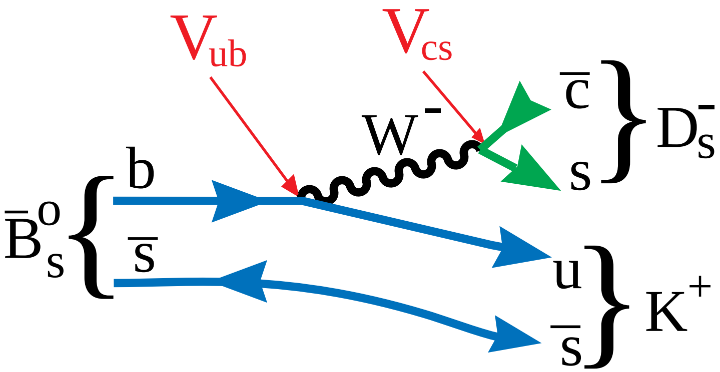
Inconsistent Results!

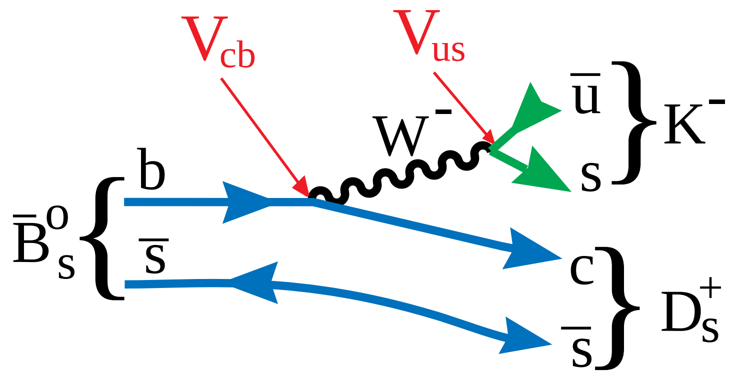
	$S_{\pi\pi}$	$C_{\pi\pi}$	$S_{\pi\pi}^2+C_{\pi\pi}^2$
Belle	-1.23±0.42	0.77±0.28	2.1±2.2
BABAR	0.02±0.34	-0.30±0.34	0.1±0.3

← Must be < 1

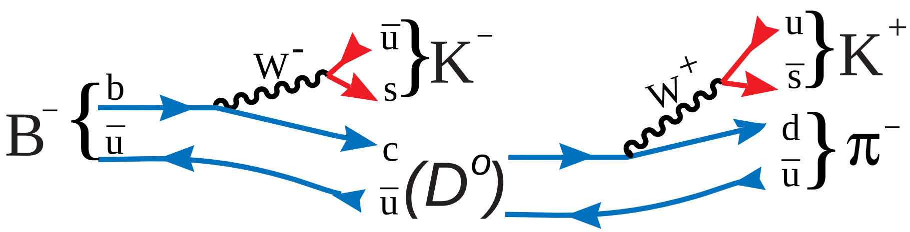
Progress on γ

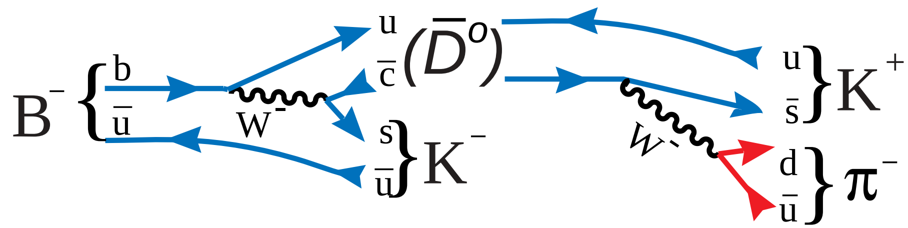
- Best way to measure γ is





- 2^{nd} best is





- Another suggestion is $D^o \rightarrow K^{*\pm}K^{\mp}$ (Grossman, Ligeti & Soffer hep-ph/0210433)

Currently available data

- Belle signals (also B^+)

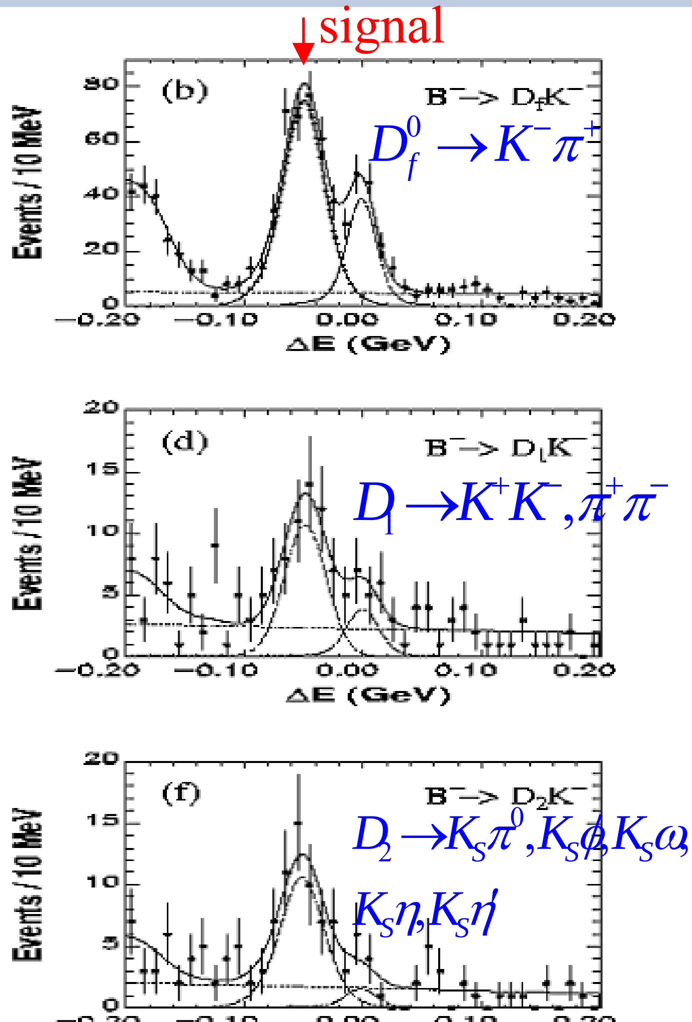
$$A_{1,2} = \frac{B(B^- \to D_{1,2}K^-) - B(B^+ \to D_{1,2}K^+)}{B(B^- \to D_{1,2}K^-) + B(B^+ \to D_{1,2}K^+)}$$

$$= \frac{\pm 2r\sin(\delta)\sin(\gamma)}{1 + r^2 \pm 2r\cos(\delta)\cos(\gamma)}$$

Where δ is a strong phase &

$$r \equiv \frac{A(B^- \to \overline{D}^0 K^-)}{A(B^- \to D^0 K^-)} = \frac{A(b \to u)}{A(b \to c)}$$

- These data do not constrain γ
- BABAR has similar results



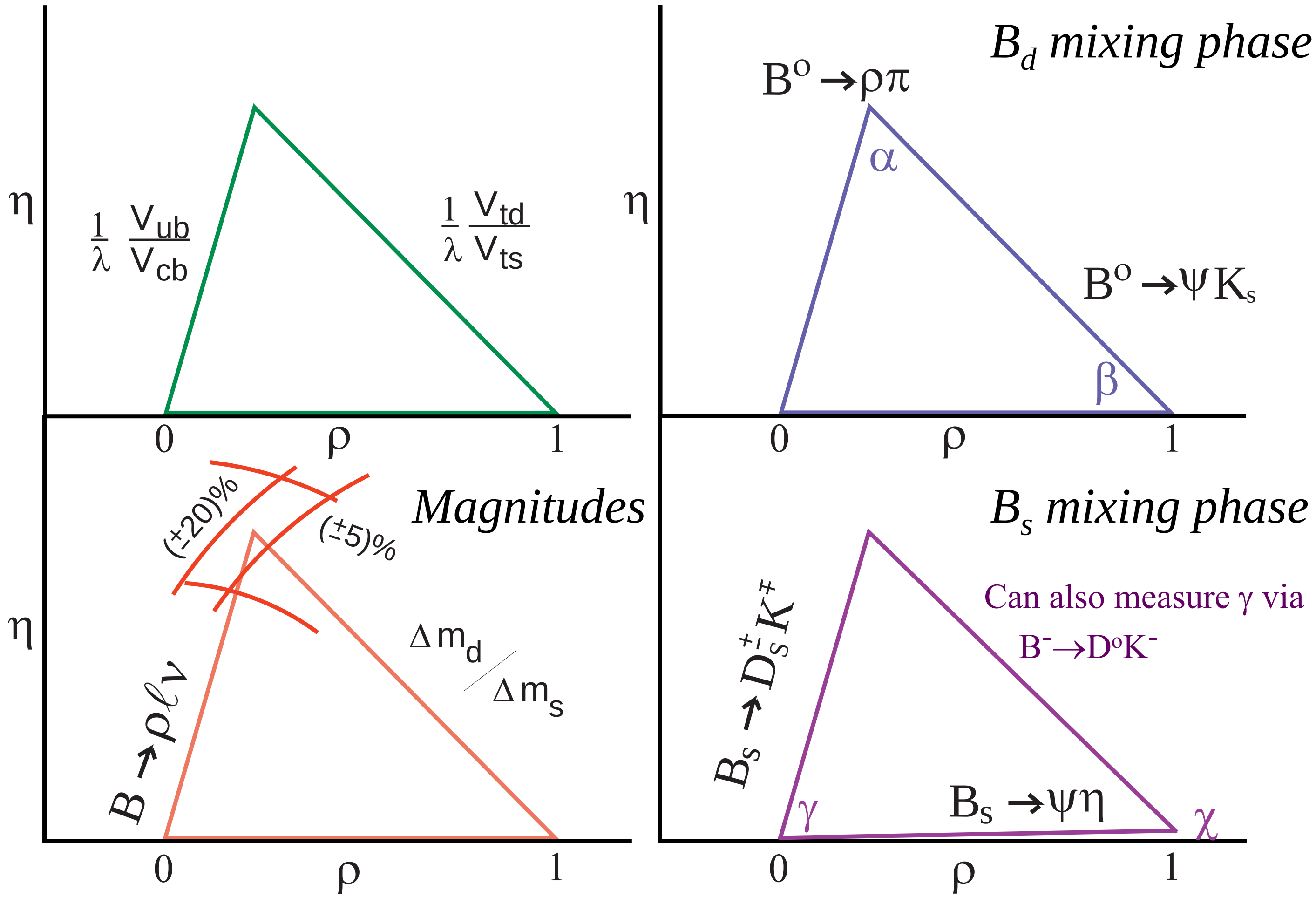
New Physics Tests

- We can use CP violating or CP related variables to perform tests for New Physics, or to figure out what is the source of the new physics.
- There are also important methods using Rare Decays, described later
- These tests can be either generic, where we test for inconsistencies in SM predictions independent of specific non-standard model, or model specific

Generic test: Separate Checks

- Use different sets of measurements to define apex of triangle

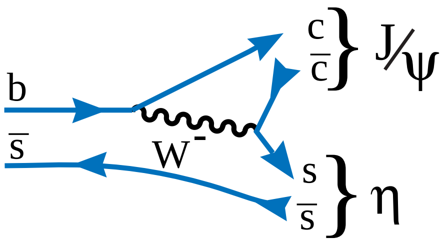
  (from Peskin)
- Also have ε_K ($\cancel{CP}$ in K_L system)



Generic Test: Critical Check using χ

- Silva & Wolfenstein (hep-ph/9610208), (Aleksan, Kayser & London), propose a test of the SM, that can reveal new physics; it relies on measuring the angle χ.
  - Can use CP eigenstates to measure χ

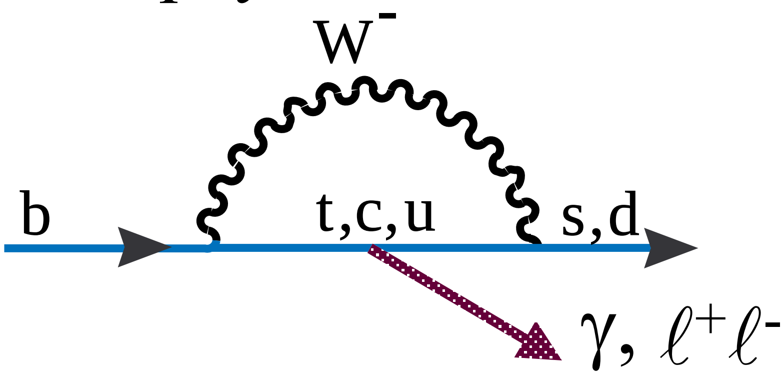
    $B_s \rightarrow J/\psi\eta^{(\prime)}$, $\eta \rightarrow \gamma\gamma$, $\eta' \rightarrow \rho\gamma$

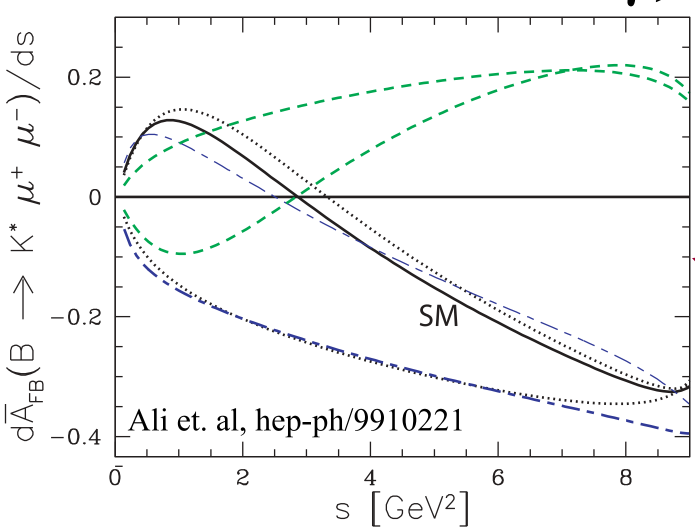


  - Can also use J/ψφ, but a complicated angular analysis is required
  - The critical check is: $$\sin\chi = \lambda^2 \frac{\sin\beta \sin\gamma}{\sin(\beta+\gamma)}$$
  - Very sensitive since $\lambda = 0.2205 \pm 0.0018$
  - Since $\chi \sim 1^{\circ}$, need lots of data

Rare b Decays

- A good place to find new physics

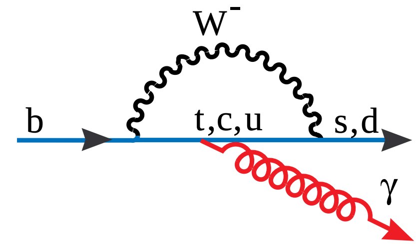




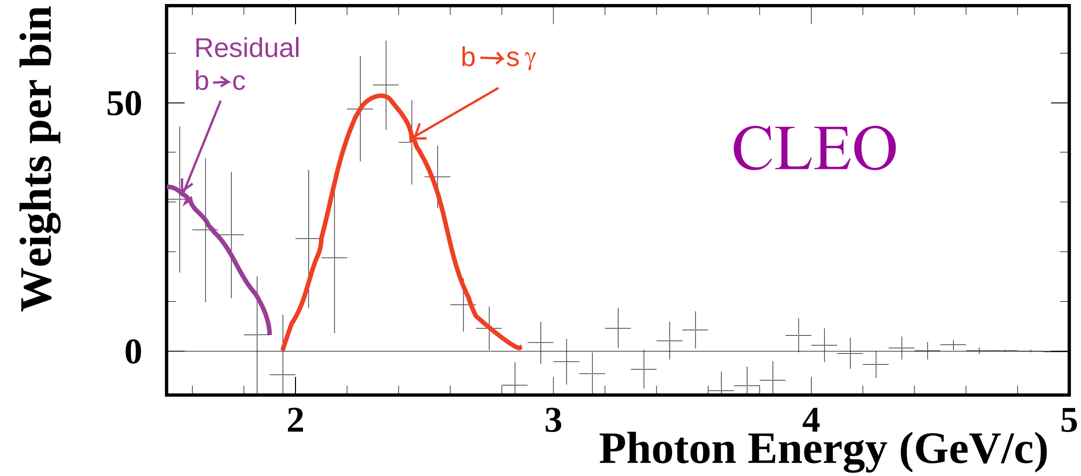
SUSY examples

- New fermion like objects in addition to t, c or u, or new Gauge-like objects
- Inclusive Rare Decays such as inclusive $b \to s\gamma$, $b \to d\gamma$, $b \to s\ell^+\ell^-$
- Exclusive Rare Decays such as $B \to \rho\gamma$, $B \to K^*\ell^+\ell^-$: Dalitz plot & polarization

Inclusive b→sγ



- CLEO *B*(b→sγ)= (2.85±0.35±0.23)x10^{-4}
- +ALEPH, Belle & Babar



Average (3.28±0.38)x10^{-4}

Theory (3.57±0.30)x10^{-4}

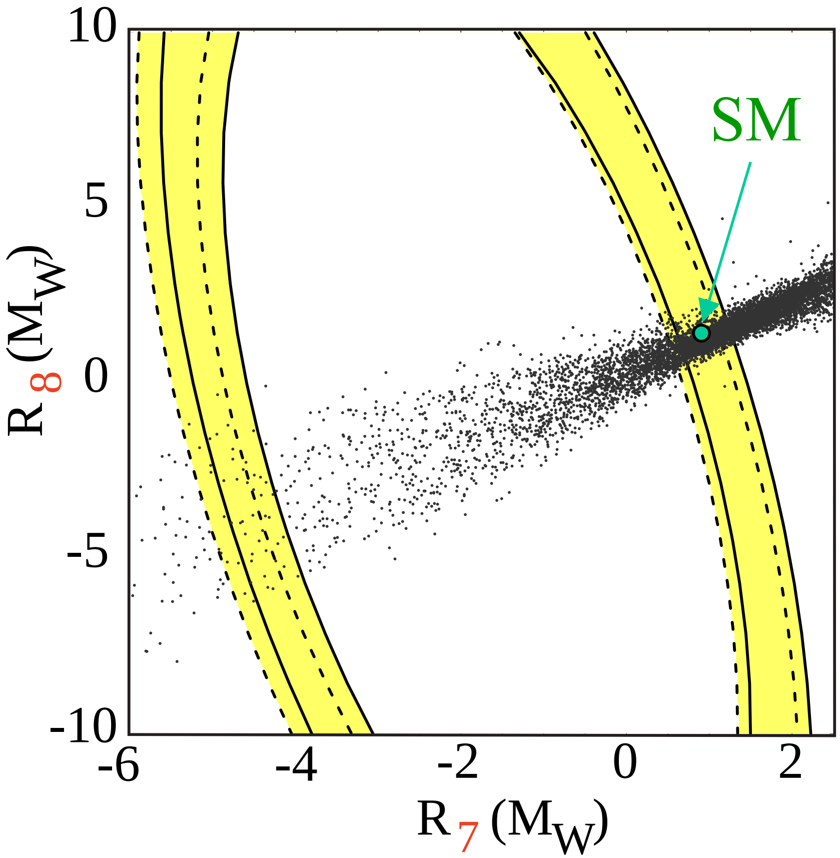
$$H_{eff} = \frac{4G_F}{\sqrt{2}}\left(V_{tb}V_{ts}^*\right)\left[c_7(m_b)O_7 + c_8(m_b)O_8\right]$$

$$O_7 = \frac{e}{16\pi^2} m_b \bar{s}_L \sigma_{\mu\nu} b_R F^{\mu\nu},\ O_8 = \frac{1}{4\pi} m_b \bar{s}_L \sigma_{\mu\nu} b_R G^{\mu\nu}$$

$$\Gamma(b \to s\gamma) = \frac{G_F^2 \alpha m_b^5}{32\pi^4}\left|c_7\right|^2 \left|V_{tb}V_{ts}^*\right|^2 \text{ in lowest order}$$

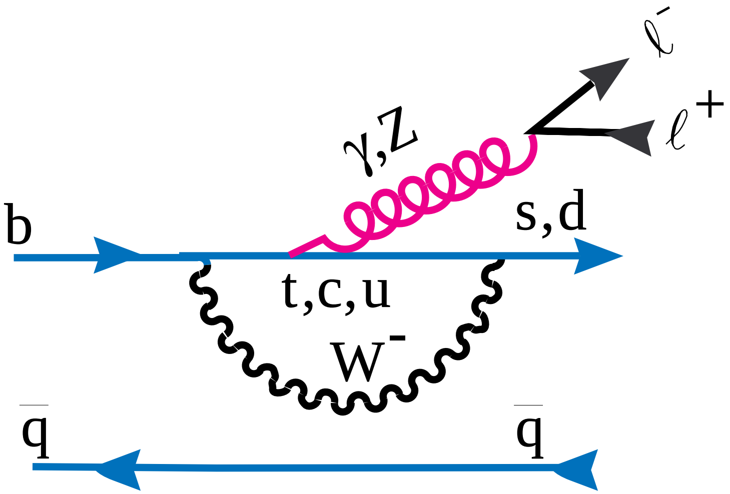
Implications of $\mathcal{B}(b \rightarrow s\gamma)$ measurement

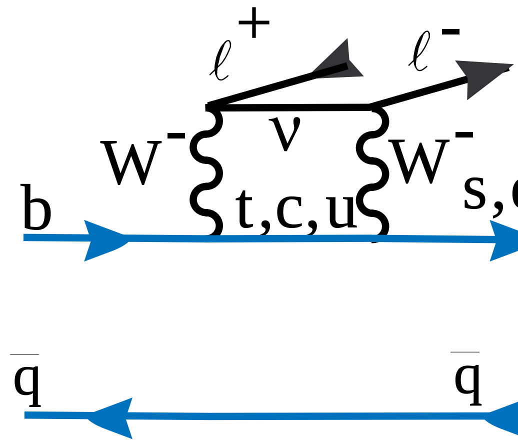
- Measurement is consistent with SM
- Limits on many non-Standard Models: minimal supergravity, supersymmetry, etc…
- Define ala' Ali et al.
  $R_i = (c_i^{SM} + c_i^{NP})/c_i^{SM}$; i=7, 8
- Black points indicate various New Physics models (MSSM with MFV)



$B \to K^{(*)}\ell^+\ell^-$

- Belle Discovery of $K\ell^+\ell^-$
- They see $K\mu^+\mu^-$
- $\mathcal{B}(B \to K\ell^+\ell^-) =$
  $$\left(0.75^{+0.25}_{-0.21} \pm 0.09\right) \mathrm{x}10^{-6}$$
- BABAR confirms in Ke^+e^-
  $\mathcal{B}(B \to K\ell^+\ell^-) =$
  $$\left(0.78^{+0.24+0.11}_{-0.20-0.18}\right) \mathrm{x}10^{-6}$$
- Only u.l. on $K^*\ell^+\ell^-$



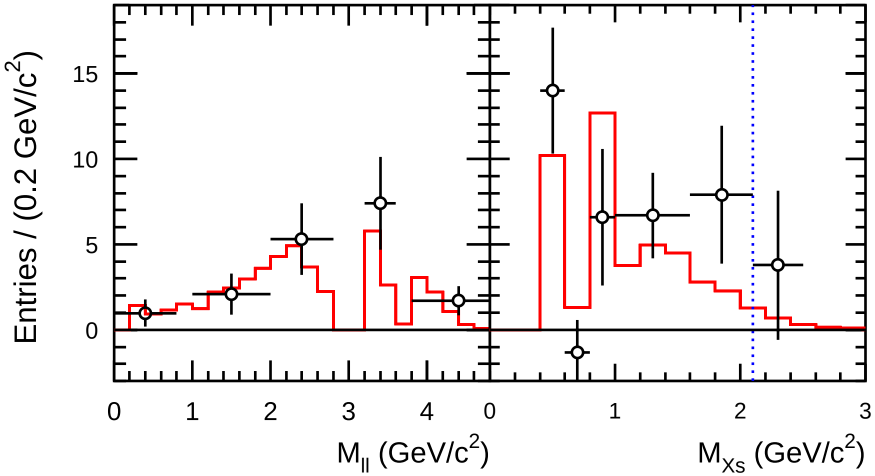


$B \to X_s \ell^+ \ell^-$

- Belle finds

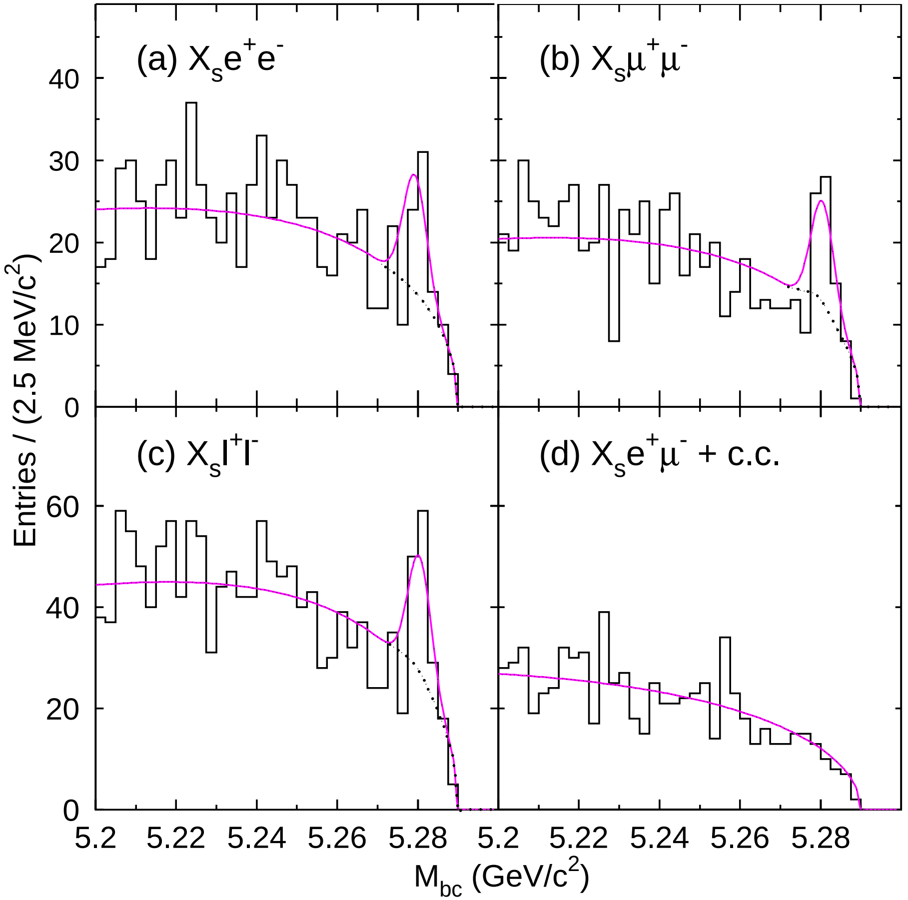
$\mathcal{B}(b \to s \ell^+ \ell^-) =$

$(6.1 \pm 1.4\ ^{+1.4}_{-1.1}) \times 10^{-6}$



- Must avoid J/Ψ, Ψ′
- Important for NP

- $H_{eff} = f(O_7, O_9, O_{10})$



Tests in Specific Models: First Supersymmetry

- Supersymmetry: In general 80 constants & 43 phases
- MSSM: 2 phases (Nir, hep-ph/9911321)
- NP in B^o mixing: θ_D , B^o decay: θ_A, D^o mixing: $\phi_{K\pi}$

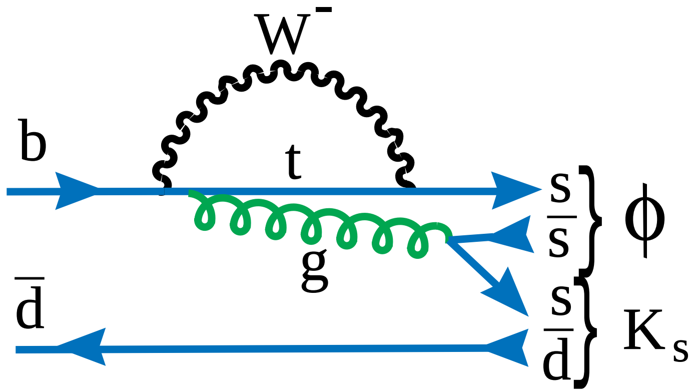
Process	Quantity	SM	New Physics
$B^o \rightarrow J/\psi K_s$	CP asym	$\sin(2\beta)$	$\sin 2(\beta+\theta_D)$
$B^o \rightarrow \phi K_s$	CP asym	$\sin(2\beta)$	$\sin 2(\beta+\theta_D+\theta_A)$
$D^o \rightarrow K^- \pi^+$	CP asym	0	$\sim\sin(\phi_{K\pi})$

Difference $\Rightarrow$ NP

NP

CP Asymmetry in $B^o \rightarrow \phi K_s$

- Non-SM contributions would interfere with suppressed SM loop diagram



- New Physics could show if there is a difference between sin(2β) measured here and in J/ψ Ks
- Measurements: BABAR: -0.18±0.51±0.07

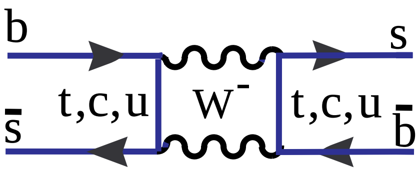
  Belle: -0.73±0.64±0.22

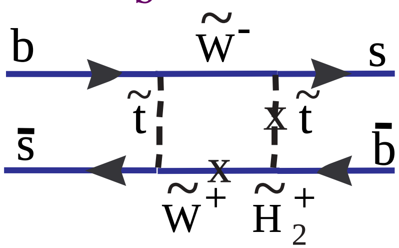
  Average: -0.38±0.41
- 2.7σ away from 0.73 - bears watching, as well other modes

MSSM Predictions from Hinchcliff & Kersting

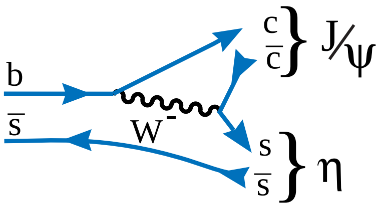
(hep-ph/0003090)

- Contributions to B_s mixing





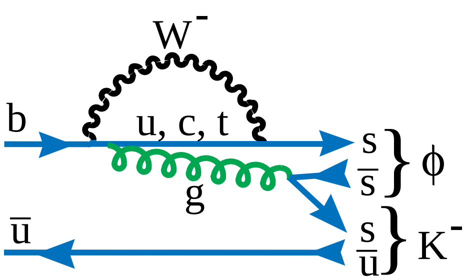
$B_s \to J/\psi\eta$

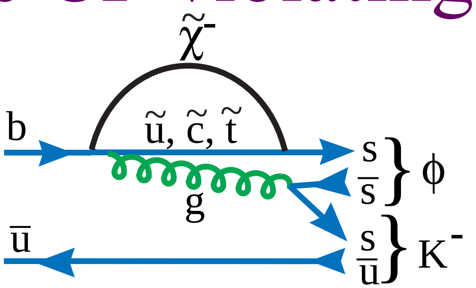


$\text{CP asymmetry} \approx 0.1\sin\phi_\mu\cos\phi_A\sin(\Delta m_s t)$, ~10 x SM

- Contributions to direct the CP violating decay

$B^- \to \phi K^-$





relies on finite strong phase shift

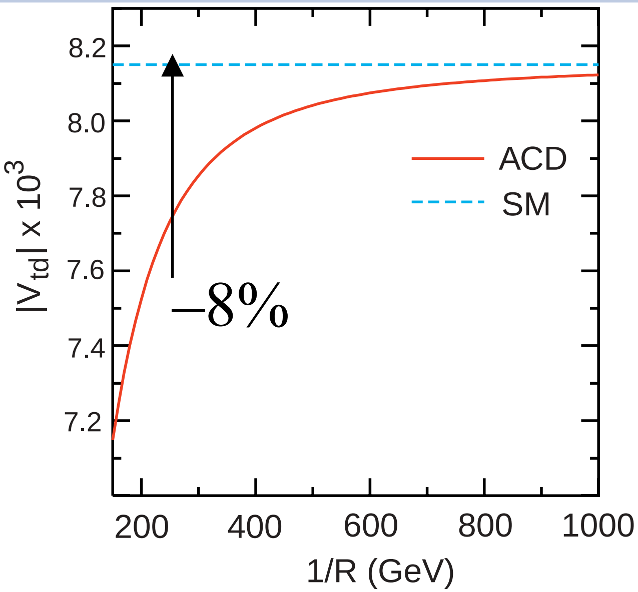
$\text{Asym}=(M_W/m_{squark})^2\sin(\phi_\mu)$, ~0 in SM

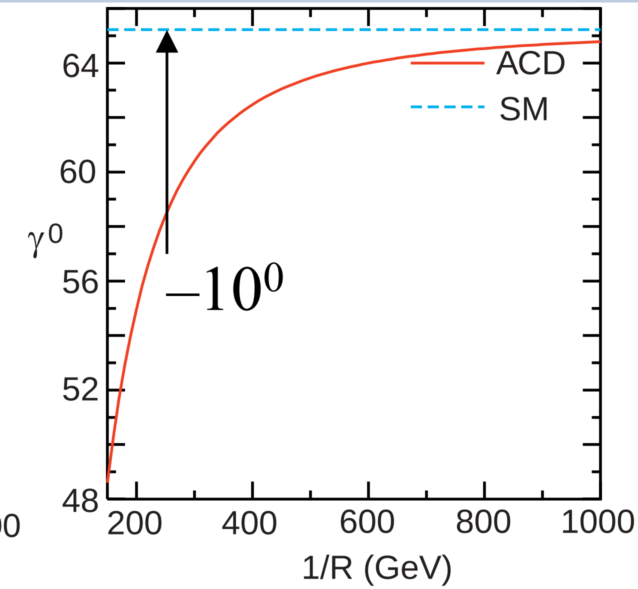
BABAR u.l
Asy=(3.9±8.6±1.1)%

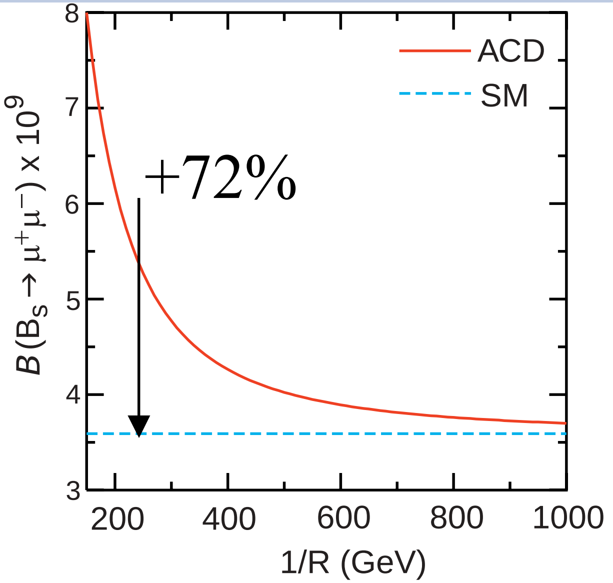
Extra Dimensions – only one

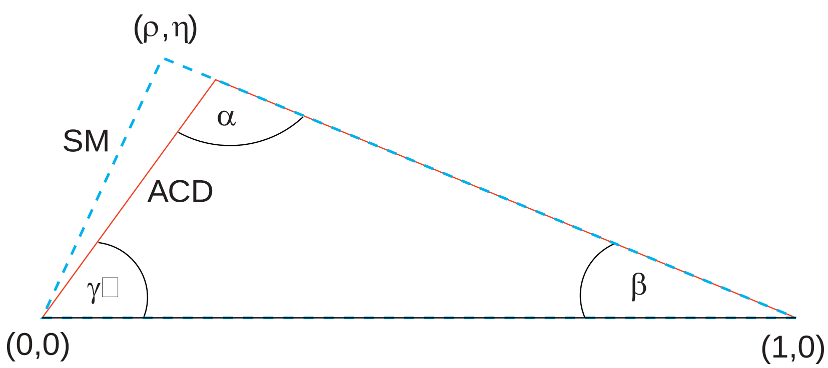
- Extra spatial dimension is compactified at scale 1/R = 250 GeV on up
- Contributions from Kaluza-Klein modes- Buras, Sprnger & Weiler (hep-ph/0212143) using model of Appelquist, Cheng and Dobrescu (ACD)
- No effect on $|V_{ub}/V_{cb}|$, $\Delta M_d/\Delta M_s$, $\sin(2\beta)$

One Extra Dimension









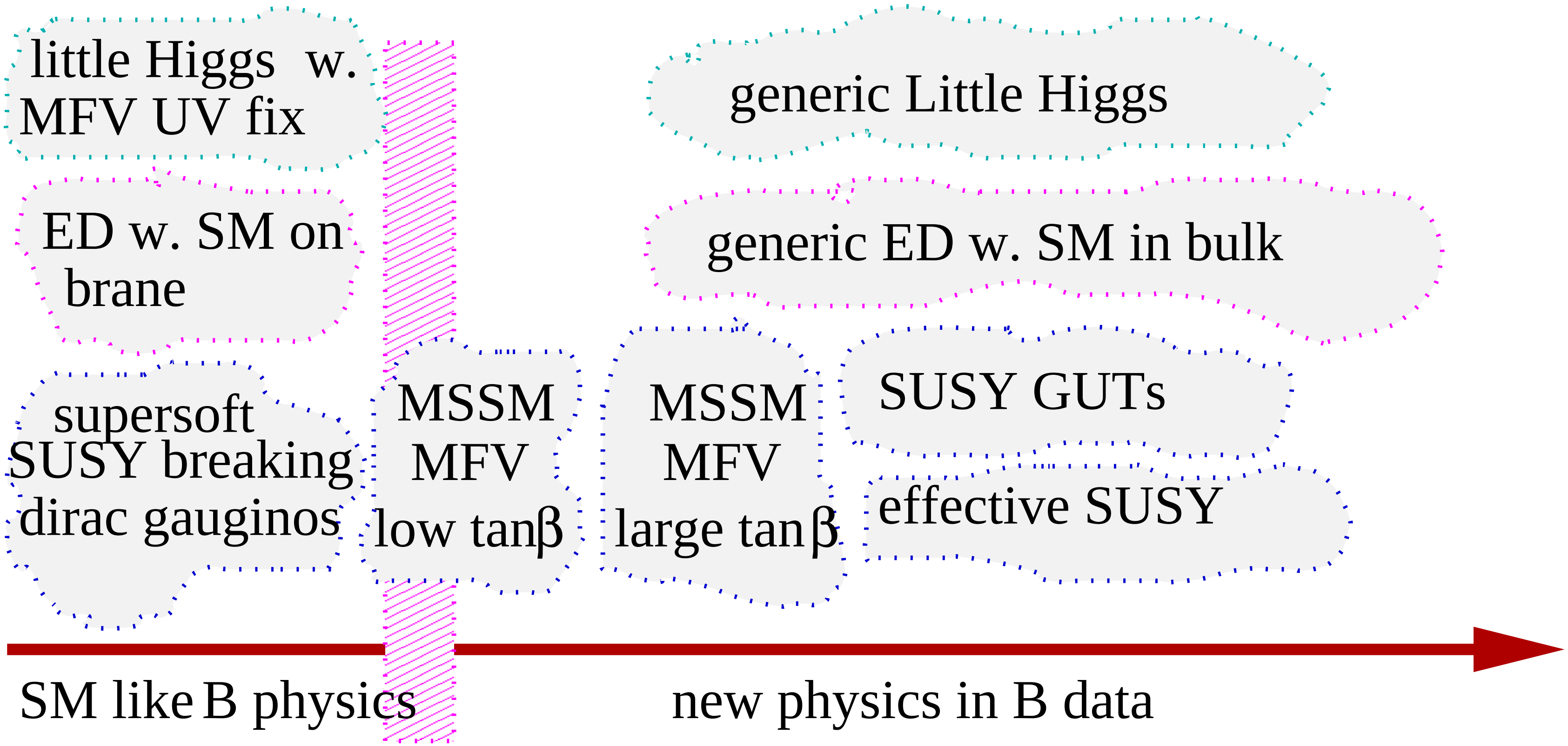
- Precision measurements needed for large 1/R

SO(10)

ala' Chang, Masiero & Murayama hep-ph/0205111

- Large mixing between ν_τ and ν_μ (from atmospheric ν oscillations) can lead to large mixing between $\tilde{b}_R$ and $\tilde{s}_R$.
- This does not violate any known measurements
- Leads to large CPV in B_s mixing, deviations from $\sin(2\beta)$ in $B^o \to \phi\, K_s$ and changes in the phase γ

Possible Size of New Physics Effects



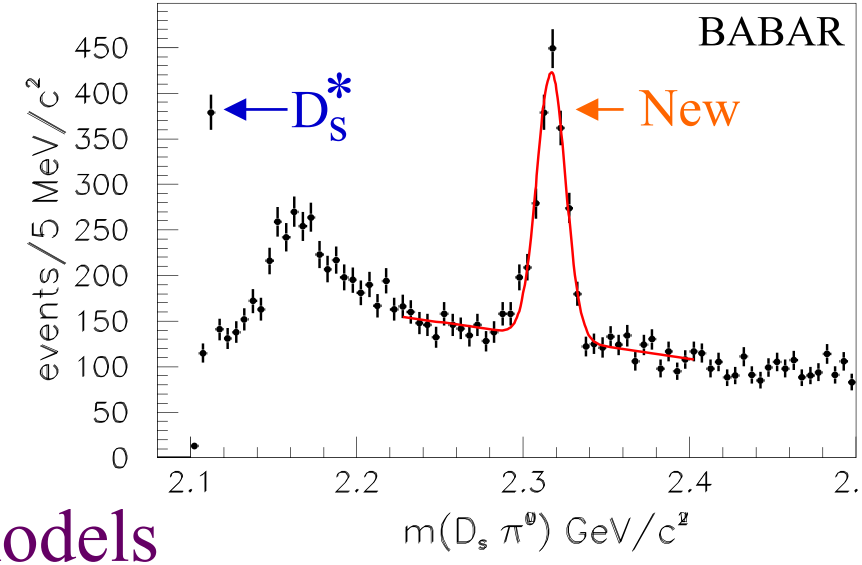
- From Hiller hep-ph/0207121

Revelations about QCD

- BABAR discovery of new narrow $D_s^+\pi^o$ state and CLEO discovery of narrow $D_s^{*+}\pi^o$ state
- Double Charm Baryons
- The $\eta_C(2S)$ and implications for Potential Models (no time)
- The Upsilon D States (no time)

The $D_s^+\pi^o$ state

- "Narrow" state, mass 2316.8±0.4±3.0 MeV width consistent with mass resolution ~9 MeV found by BABAR



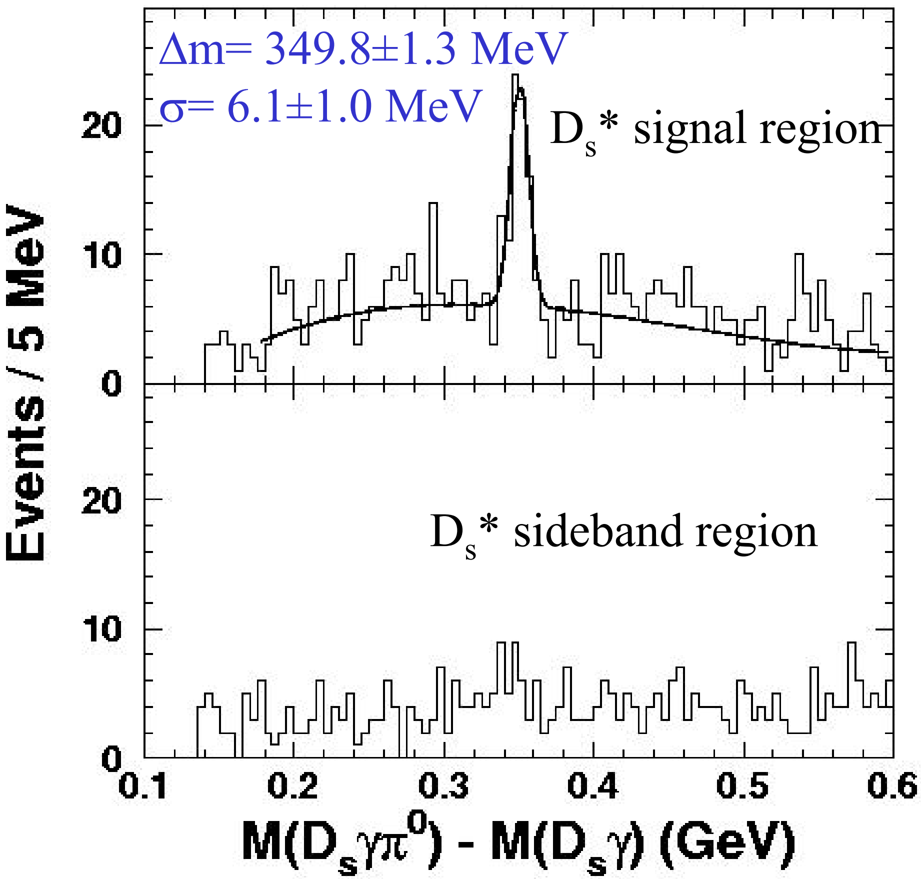
- Lighter than most potential models
- What can this be?
  - DK molecule Barnes, Close & Lipkin hep-ph/0305025
  - "Ordinary" excited $c\bar{s}$ states: D**, narrow because isospin is violated in the decay. Use HQET + chiral symmetry to explain. Bardeen, Eichten & Hill hep-ph/0305049
  - Etc…

D_s^{+}** States

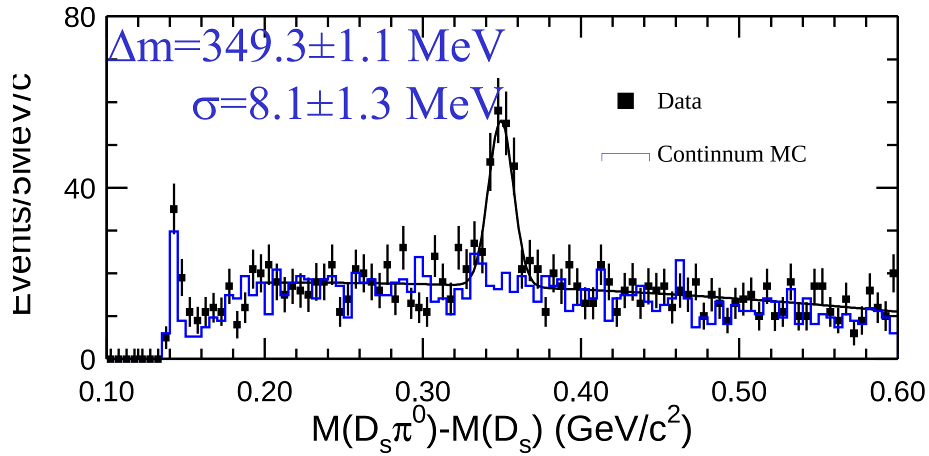
- D_s** predicted J^p: 0^+, 1^+, 1^+ & 2^+. One 1^+ & 2^+ seen. Others predicted to be above DK threshold and have large ~200 MeV widths, but this state is way below DK threshold
- The $D_s^{+}\pi^o$ decay from an initial $c\bar{s}$ state violates isospin, this suppresses the decay width & makes it narrow. So the low mass ensures the narrow width
- Decays into $D_s^{+}\gamma$, $D_s^{+}{}^*\gamma$ and $D_s^{+}\pi^+\pi^-$ are not seen. If the 2317 were 1^+ then it could decay strongly into $D_s^{+}\pi^+\pi^-$ but it cannot if it's 0^+

CLEO Sees Two Mass Peaks

$D_s^*\pi^o$

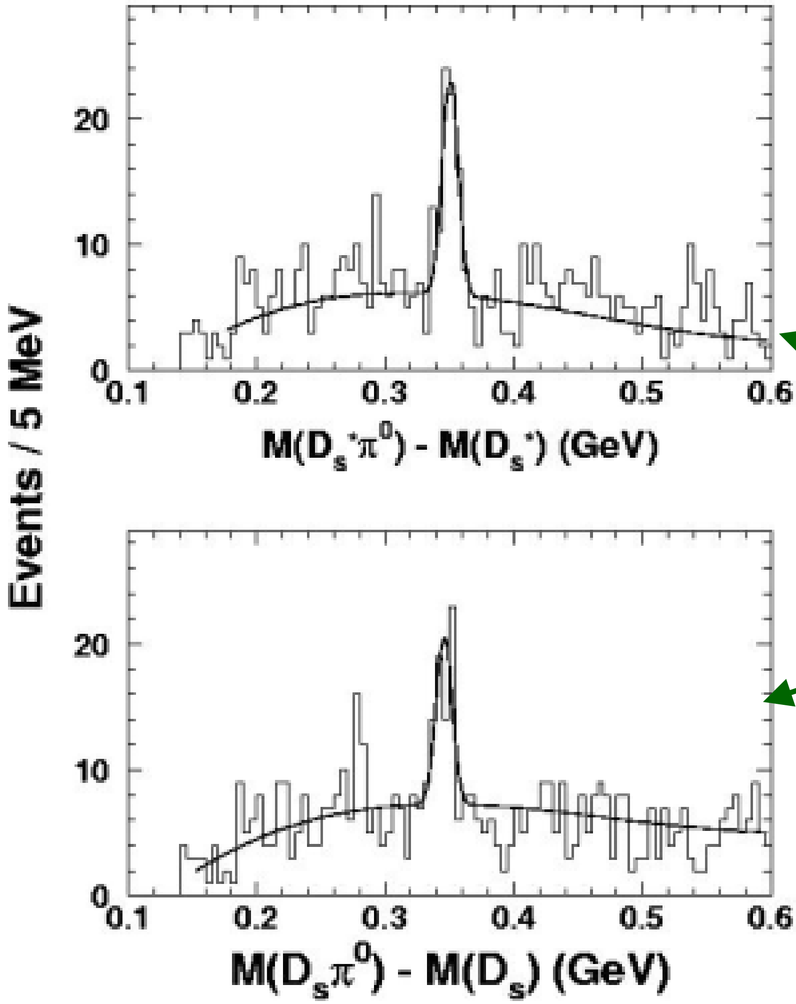


$D_s\pi^o$



- These two states can reflect into one another
- $D_s\pi^o \rightarrow D_s^*\pi^o$ not to bad, ~9%, because you need to pick up a random γ

Feed Down: $D_s(2460)$ Signal, Reconstructed as $D_s(2317)$



All events in the $D_s{}^*\pi^0$ mass spectrum are used to show the $D_s(2460)$ signal "feed down" to the $D_s(2317)$ spectrum.

Feed down rate is 84%

Unfolding the rates

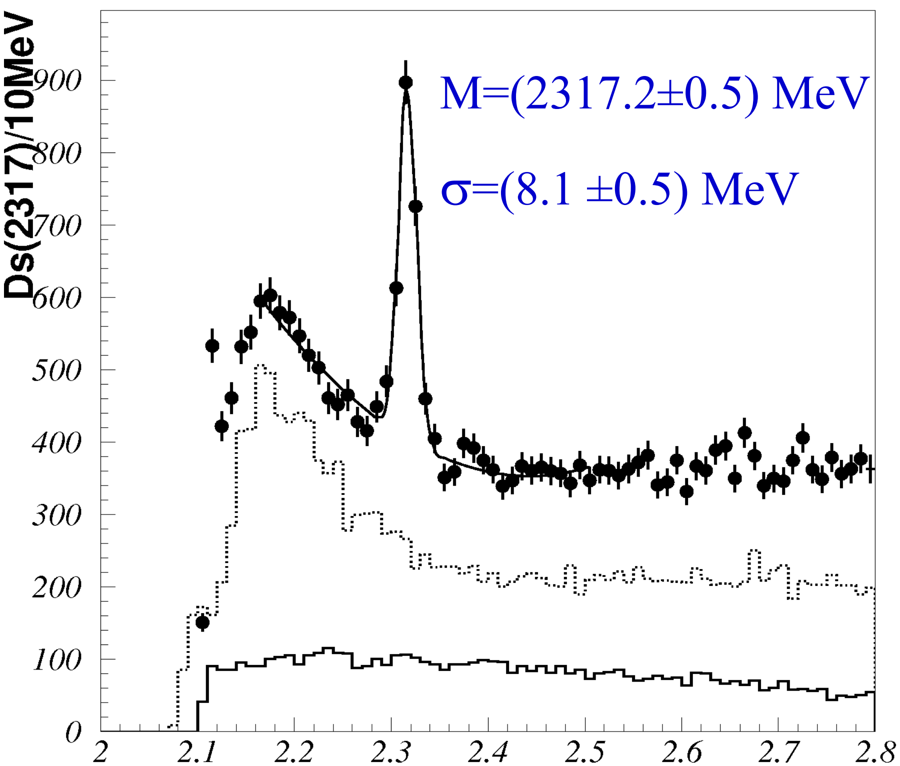
- We are dealing with two narrow resonances which can reflect (or feed) into one another
- From the data and the MC rates can be unfolded

Upper Limits on other $D_s(2317)$ modes

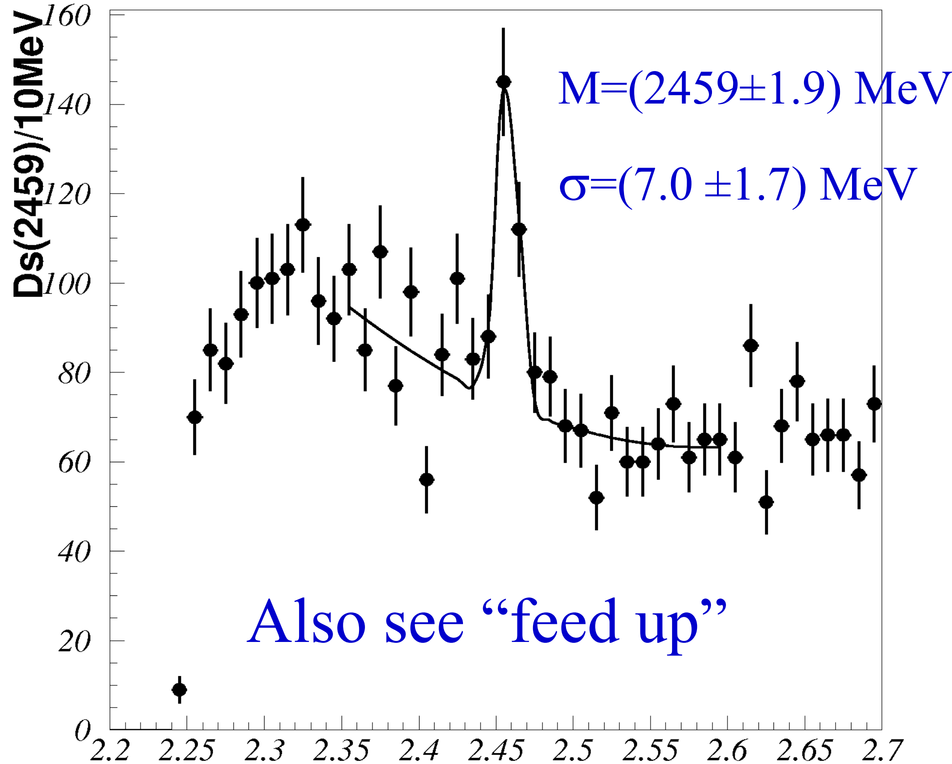
Mode	Yield	Efficiency(%)	90% cl	Theory
$D_s\pi^o$	150±49	13.1±0.7	-	1
$D_s\gamma$	-22±13	18.4±0.9	<0.057	0
$D_s^*\gamma$	-2.0±4.1	5.3±0.4	<0.078	0.08
$D_s\pi^+\pi^-$	1.6±2.6	19.6±0.7	<0.020	0

- Corrected for feed across
- Theory: Bardeen, Eichten and Hill

Belle Confirms Both States



$M(D_s^+ \pi^0)$



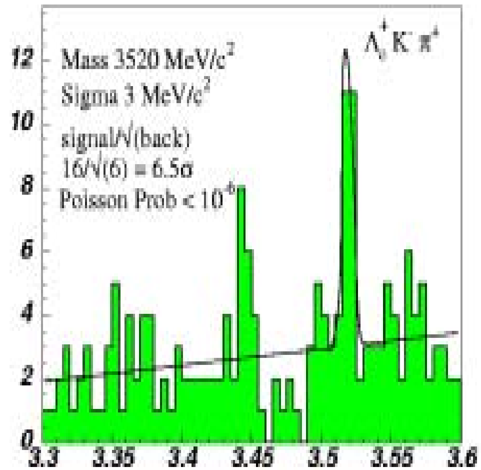
$M(D_s^{*+} \pi^0)$

Conclusions on D_s**'s

- CLEO confirms the BABAR discovered narrow $c\bar{s}$ state near 2317 MeV, measures $mD_s(2320)-mD_s = 350.4\pm1.2\pm1.0$ MeV
- CLEO has observed a new narrow state near 2463

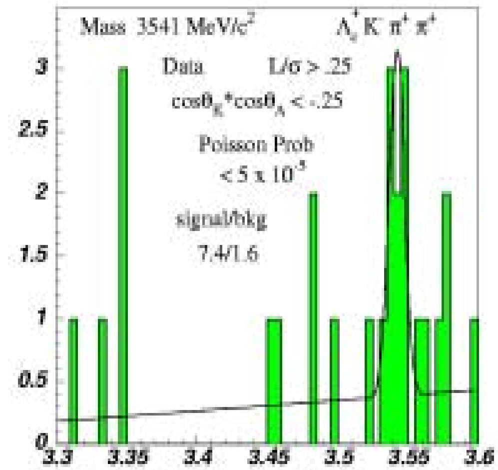
  $mD_s(2463)-mD_s^* = 351.6\pm1.7\pm1.0$ MeV
- Belle confirms both states
- The mass splittings are consistent with being equal (1.2 ± 2.1 MeV) as predicted by BEH if these are the 0^+ & 1^+ states
- The BEH model couples HQET with Chiral Symmetry and makes predictions about masses, widths and decay modes.
  - These results provide powerful evidence for this model
  - Seen modes and u.l. are consistent with these assignment; except $1^+ \to D_s\pi^+\pi^-$ is above threshold for decay, predicted to be 19% but is limited to <8.1% @ 90% c. l.

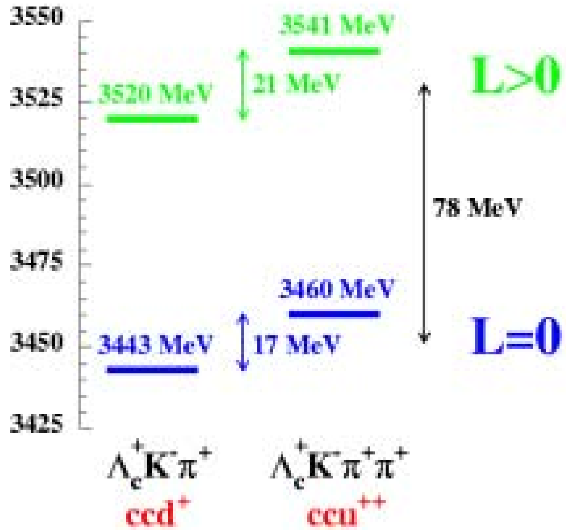
Selex: Two Isodoublets of Doubly Charmed Baryons

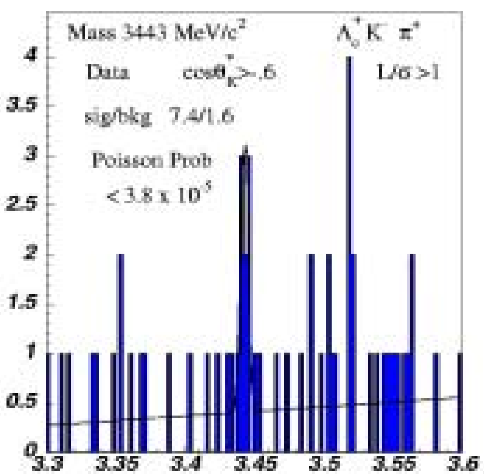


Ξ_{cc}^{+} (J=1/2$^-$)?

Ξ_{cc}^{++} (J=1/2$^-$)?

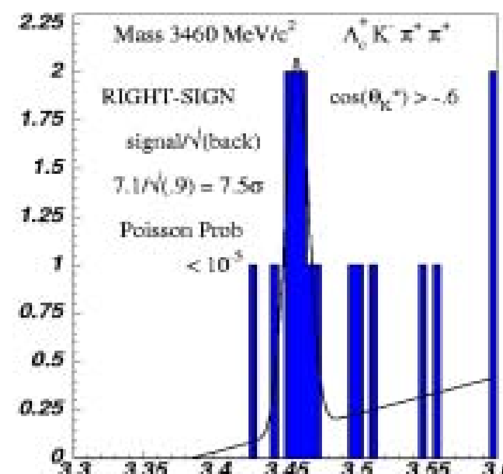






Ξ_{cc}^{+} (J=1/2$^+$)?

Ξ_{cc}^{++} (J=1/2$^+$)?



Consider as (cc)q - BEH

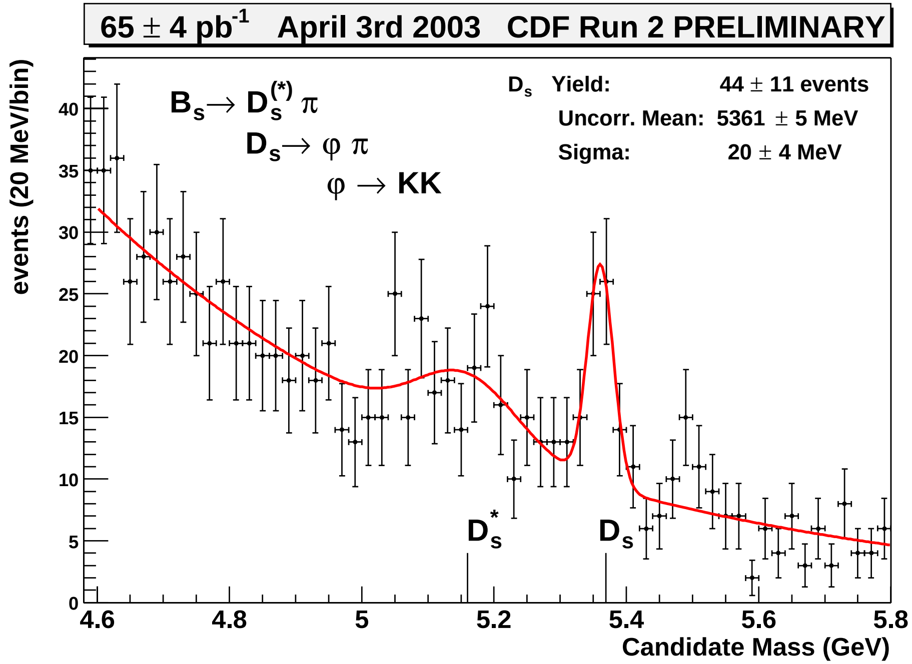
The Future

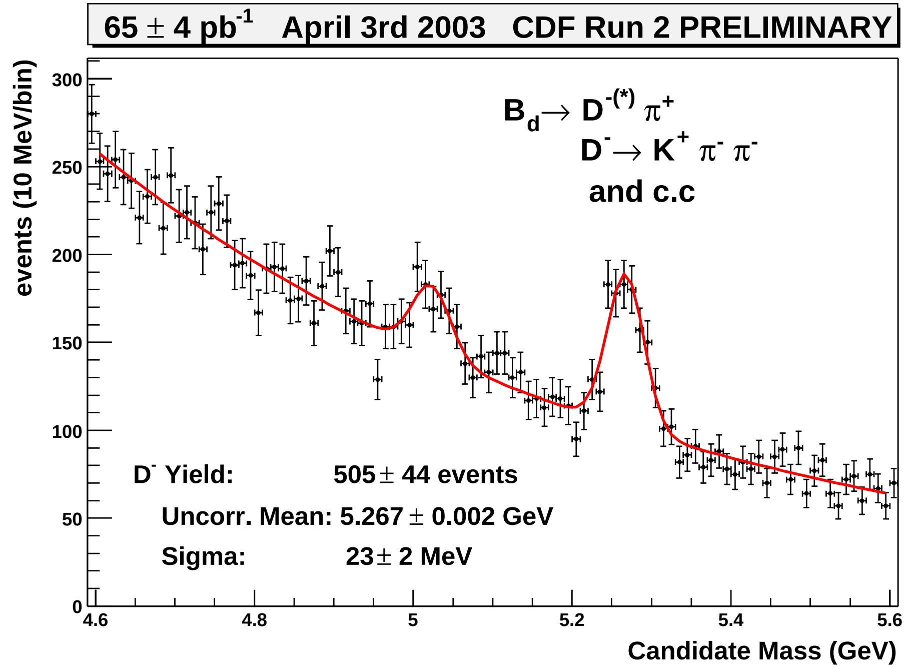
- Now & near term
  - Continuation of excellent new results from Belle & BABAR
  - B_s physics, especially mixing from CDF & D0
  - CLEO-c will start taking data in October on ψ''
- LHC era
  - Some b physics from ATLAS & CMS
  - Dedicated hadronic b experiments: LHCb & BTeV (at the Tevatron) – enhanced sensitivity to new physics

Summary of Required Model Independent Measurements for CKM tests

Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^o \to \rho\,\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\cos(2\alpha)$	$B^o \to \rho\,\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\sin(\gamma)$	$B_s \to D_s\,K^-$	✓	✓		✓
$\sin(\gamma)$	$B^o \to D^o\,K^-$	✓	✓		
$\sin(2\chi)$	$B_s \to J/\psi\,\eta'$, $J/\psi\,\eta$		✓	✓	✓
$\sin(2\beta)$	$B^o \to J/\psi\,K_s$				
$\cos(2\beta)$	$B^o \to J/\psi\,K^o$, $K^o \to \pi\ell\nu$		✓		
x_s	$B_s \to D_s\,\pi^-$	✓	✓		✓
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\,\eta'$, K^+K^-, $D_s\,\pi^-$	✓	✓	✓	✓

CDF measures $\bar{B}_s^o \rightarrow D_s^+ \pi^-$ needed for B_s mixing

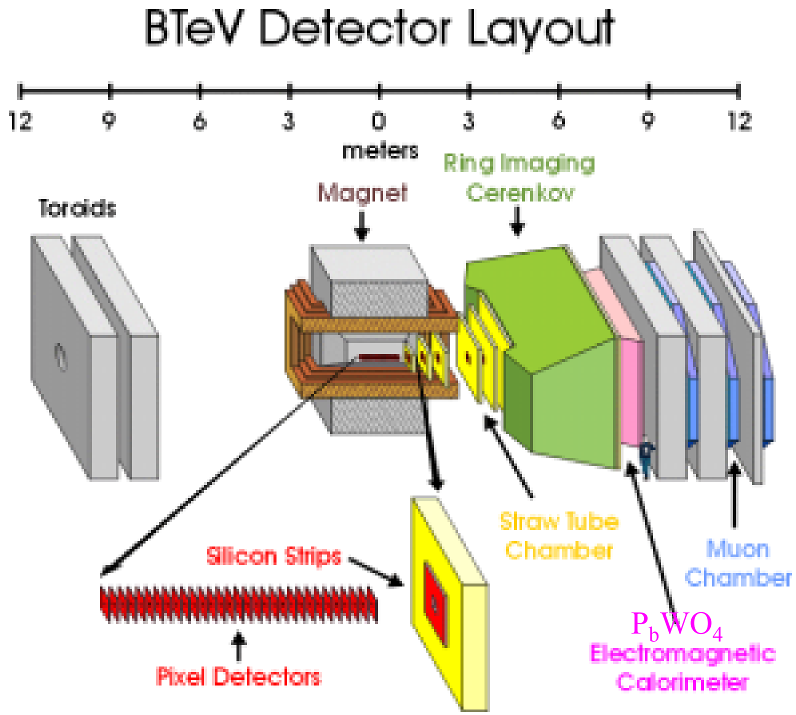


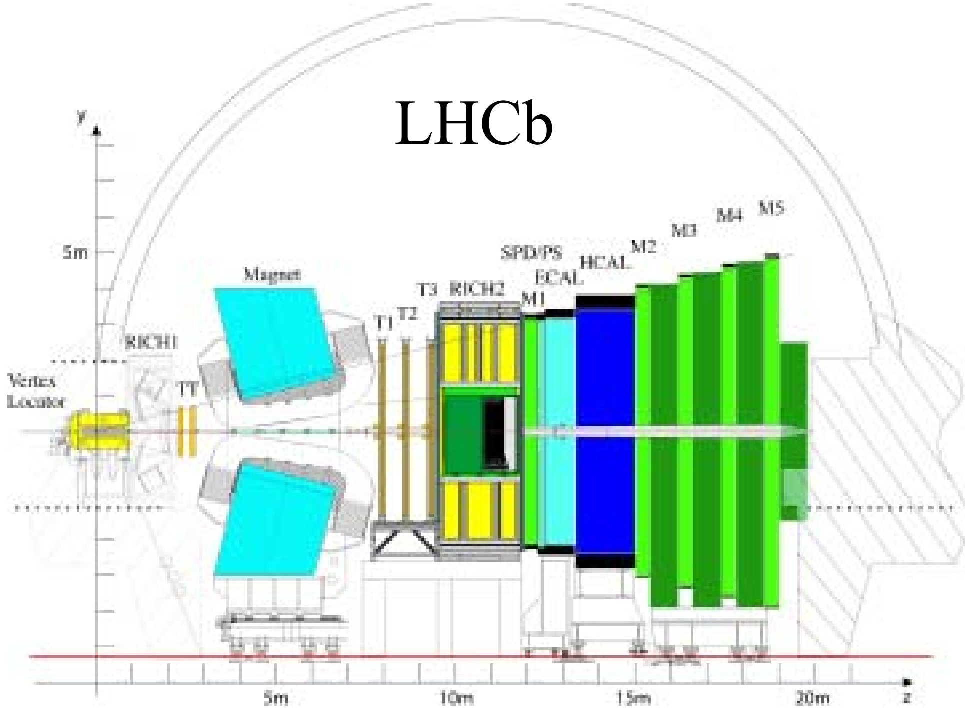


- $$\frac{f_s B(\bar{B}_s^o \rightarrow D_s^+ \pi^-)}{f_d B(\bar{B}_d^o \rightarrow D^+ \pi^-)} = 0.42 \pm 0.11 \pm 0.11^{+0.06}_{-0.07}$$
- For $f_s/f_d = 0.27 \pm 0.03$, $B(B_s)/B(B_d) = 1.6 \pm 0.3$

BTeV & LHCb

- Dedicated Hadron Collider B experiments
- Tevatron LHC





Could find narrow B_s** states

BTeV & LHCb

- Physics highlights
  - Sensitivity to B_s mixing up to x_s ~80
  - Large rare decay rates $B^o \rightarrow K^{*o}\mu^+\mu^-$ ~2500 events in 10^7 s
  - Measurement of γ to ~7^o using $B_s \rightarrow D_s K^-$
  - Measurement of α to ~4^o using $B^o \rightarrow \rho\pi$ (BTeV)
  - Measurement of χ to ~1^o using $B^o \rightarrow J/\psi\eta$ (BTeV)

Conclusions

- There have been lots of surprises in Heavy Quark Physics, including:
  - Long b Lifetime
  - $B^o - \overline{B}^o$ mixing
  - Narrow D_s** states
- We now expect to find the effects of New Physics in b & c decays!